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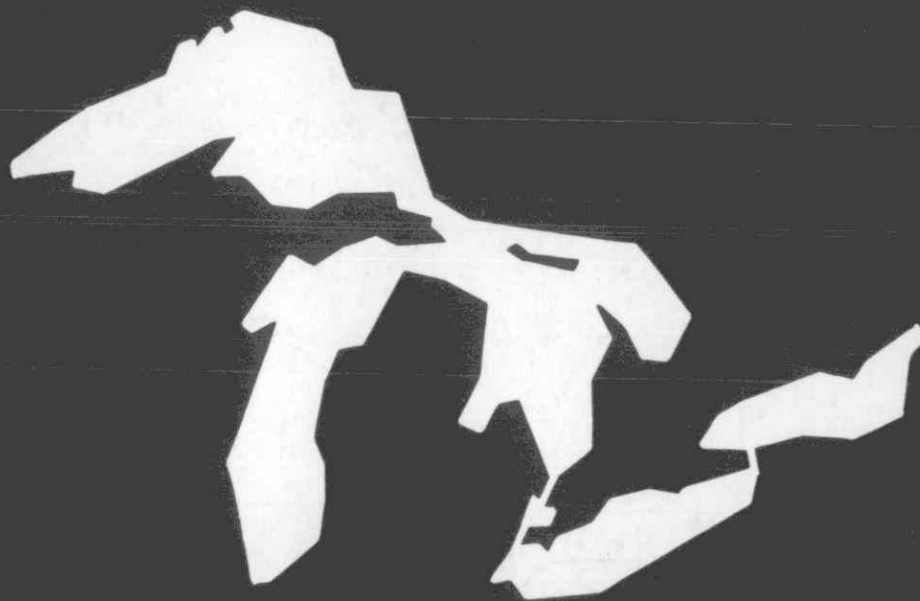
Canada - Ontario Agreement on Great Lakes Water Quality



Ministry
of the
Environment

Pilot Scale Evaluation of a Physical-Chemical Wastewater Treatment System for Combined Sewer Overflows

Research Report No. 36



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Research Program for the Abatement of Municipal Pollution
under Provisions of the Canada- Ontario Agreement
on Great Lakes Water Quality

Research Report No. 36

Physical-Chemical Wastewater Treatment System

1976

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These RESEARCH REPORTS describe the results of investigations funded under the Research Program for the Abatement of Municipal Pollution within the Provisions of the Canada-Ontario Agreement on Great Lakes Water Quality. They provide a central source of information on the studies carried out in this program through in-house projects by both Environment Canada and the Ontario Ministry of the Environment, and contracts with municipalities, research institutions and industrial organizations.

The Scientific Liaison Officer for this project was
Dr. A. Netzer, Environment Canada.

Enquiries pertaining to the Canada-Ontario Agreement RESEARCH PROGRAM should be directed to -

Wastewater Technology Centre,
Canada Centre for Inland Waters,
Environment Canada,
P.O. Box 5050,
Burlington, Ontario L7R 4A6

Ontario Ministry of the Environment,
Pollution Control Branch,
135 St. Clair Avenue West,
Toronto, Ontario M4V 1P5

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MINISTRY OF THE
ENVIRONMENT

PILOT SCALE EVALUATION OF A PHYSICAL-CHEMICAL
WASTEWATER TREATMENT SYSTEM FOR COMBINED
SEWER OVERFLOWS

by

Pollutech Pollution Advisory Services Ltd.
Oakville, Ontario

RESEARCH PROGRAM FOR THE ABATEMENT
OF MUNICIPAL POLLUTION WITHIN THE
PROVISIONS OF THE CANADA-ONTARIO
AGREEMENT ON GREAT LAKES WATER QUALITY

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ABSTRACT

This report describes a pilot scale investigation of the feasibility of using coarse screening, microscreening, and ozonation for the treatment of combined sewer overflows. The pilot scale system consisted of a Crane-Cochrane Microstrainer with 23 micron screen openings and an ozone generator.

During the first part of the study, the pilot unit was installed at the West Oakville Water Pollution Control Plant. The dilute waste concentrations anticipated in combined sewer overflows were simulated by diluting raw sewage with tapwater. The contaminants measured were BOD, total organic carbon, suspended solids, total phosphorus, oil and grease, and total coliforms.

The effects of waste strength and hydraulic loading were studied by varying the dilution of the raw waste and controlling the throughput of the unit. It was found that the contaminant removal efficiency decreased with the degree of dilution of the raw sewage, and as the hydraulic loading on the Microstrainer increased.

The effect of ferric chloride and polyelectrolyte chemical addition prior to microscreening was investigated, but no beneficial effect on the treatment efficiency was observed.

Ozonation was found to reduce the concentration of all measured contaminants including suspended solids. At a 20 mg/l ozone dosage in a continuous ozonation reactor with a nominal 15 minute retention time, COD removals of 40 to 50 percent were observed. Microscreened raw sewage spiked with lead to simulate street runoff showed a 35 percent reduction in lead concentration.

The average removal efficiency of the pilot scale treatment system for all experimental conditions was 67% BOD₅ removal, 40% suspended solids removal, 26% total phosphorus removal, and greater than 99.9% total coliform reduction. Total organic carbon, oil and grease, and colour removals were 28%, 50%, and 64%, respectively.

During the second part of the study the pilot scale was installed at a combined sewer outfall in Hamilton, Ontario, and the efficiency of the system was evaluated in terms of the removal of BOD, suspended solids total coliforms, total phosphorus, oil and grease, and total organic carbon during three separate storms.

The actual combined sewer overflows were found to contain a higher concentration of inorganic solids, primarily finely dispersed clay particles, and significantly less organic contaminants than the synthetic waste used in the first part of the study.

The average overall efficiency of the pilot scale treatment system for all runs under actual operating conditions was 29.2% BOD removal, 29.6% suspended solids removal, 76% total coliform reduction and 39.4% oil and grease removal. True colour, total phosphorus and total organic carbon removals were 35%, 19.6% and 11.2%, respectively.

The removal in terms of all measured parameters was less than that attained by the system applied to the synthetic waste during the first part of the study. No correlation between hydraulic loading or suspended solids loading of the system and the performance was evident.

RÉSUMÉ

Le présent rapport donne le compte rendu d'une étude des caractéristiques techniques du tamisage grossier, du micro-tamisage et de l'ozonation des eaux combinées des déversoirs d'orage, réalisée à l'échelle pilote. Le dispositif à l'étude consistait en un micro-tamis Crane-Cochrane à ouvertures de 23 microns et en un générateur d'ozone.

Dans la première partie de l'étude, l'unité a été installée dans l'usine de traitement de West Oakville. On y a réalisé la simulation des concentrations des rejets dilués, prévues pour être celles qu'on observerait dans les eaux combinées des déversoirs d'orage, par dilution des eaux brutes avec de l'eau propre. On a mesuré la DBO, les teneurs en carbone organique total, en matières en suspension, en phosphore total, en huiles et en graisses ainsi que le nombre total d'organismes coliformes.

On a étudié l'effet de la concentration des eaux usées et de la charge hydraulique, en faisant varier le taux de dilution des eaux brutes et le débit du traitement. On a observé que l'efficacité du traitement diminuait avec le taux de dilution des matières brutes et avec l'augmentation de la charge hydraulique subie par le micro-tamis.

On a aussi étudié l'effet de l'addition de chlorure ferrique et de polyélectrolytes, préalable au tamisage, mais on n'a pu en dégager aucun avantage.

L'ozonation s'est révélée efficace à l'égard de tous les paramètres et contaminants mesurés, y compris les matières en suspension. Avec un apport de 20 mg d'ozone par litre, par un réacteur fonctionnant en continu, suivi d'une rétention théorique de 15 minutes, on a constaté une réduction de 40 à 50% de la demande chimique d'oxygène. Les eaux brutes enrichies de plomb, après leur passage au micro-tamis, de façon à ressembler aux eaux de ruissellement urbaines, ont été débarrassées de 35% de leur plomb.

L'efficacité moyenne de l'installation pilote, dans toutes les conditions d'expérience a été de 67% pour la DBO_5 , de 40% pour les

matières en suspension, de 26% pour le phosphore total, et supérieure à 99.9% pour les organismes coliformes totaux. Elle a été de 28, de 50, et de 64% pour le carbone organique total, les huiles et les graisses et pour la décoloration, respectivement.

Au cours de la deuxième partie de l'étude, l'unité pilote a été installée près d'un point de décharge d'eaux combinées d'égout, à Hamilton Ontario, et on en a évalué l'efficacité à l'égard de la réduction de la DBO, du nombre total d'organismes coliformes, et des teneurs en matières en suspension, en phosphore total, en graisses et huiles et en carbone organique total, au cours de trois épisodes de pluies distinctes.

On a constaté qu'en réalité les eaux combinées des déversoirs d'orage étaient plus riches en matières minérales, constituées surtout de particules d'argile finement divisées, et notablement moins riches en contaminants organiques que les eaux usées synthétiques utilisées dans la première partie de l'étude.

L'efficacité moyenne de l'unité pilote pour l'ensemble des épisodes étudiés a été de 29.2% pour la DBO, 76% pour les organismes coliformes totaux, et 39.4% pour les huiles et les graisses. Elle a été de 35, de 19.6 et de 11.2% respectivement pour l'élimination de la couleur vraie, du phosphore total et du carbone organique total.

Ainsi, dans des conditions réelles, l'efficacité était moindre que dans des conditions simulées, celles de la première partie de l'étude. Aucune corrélation entre la charge hydraulique ou la teneur en matières en suspension et entre l'efficacité du dispositif n'était évidente.

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PART I

1. INTRODUCTION

Obvious deterioration in the quality of the Great Lakes watershed has led to a re-evaluation of the practice of discharging untreated wastes to the natural watercourse. A significant source of contaminants is the overflow from combined sewage collection systems under storm conditions. A large number of municipalities in the Great Lakes region are served by such combined sewer systems which transport both sanitary wastes and storm runoff waters.

Numerous systems including separate sewer systems, stormwater retention ponds and in-stream physical and chemical treatment schemes have been proposed as a means of controlling or reducing this pollutional load. Pollutech Pollution Advisory Services Limited was retained under the provisions of the Canada-U.S. Agreement on Great Lakes Water Quality, to determine the applicability and feasibility of an advanced physical-chemical treatment concept consisting of fine screening and ozonation, for high-rate treatment of wastes from combined sewer overflows.

2. OBJECTIVES

The primary objective of the investigation was to assess the potential of the microscreen-ozone system for the high-rate treatment and abatement of pollution resulting from combined sewer overflows.

The scope of the study encompassed:

- The design, installation and debugging of a pilot scale treatment system consisting of a microstrainer, and ozonation facilities and evaluation of the applicability of the system for treating combined sewer overflows as simulated by diluted raw sewage.
- The evaluation of the feasibility of using inorganic and organic chemical additives prior to microscreening as a means of precipitating phosphorus.
- The evaluation of the effectiveness of ozone for disinfection and polishing of the screened sewage.
- The evaluation of the ability of ozone to remove lead contaminants entering the sewage system from snow-melt runoff.
- The preparation of an approximate cost estimate for a full scale treatment system.

3. TECHNICAL BACKGROUND

An enormous polluttional load is placed on the receiving waters by combined sewer overflows. It has been estimated that the total pounds of BOD and suspended solids contributed annually to the receiving waters by such overflows are of the same magnitude as that discharged from all secondary treatment facilities. Combined sewer overflow consists of a mixture of stormwater and sanitary wastes. These two components are somewhat similar in composition, both containing suspended solids, BOD and coliform concentrations greatly exceeding that in typical secondary treatment plant effluents.

The flowrate of stormwater runoff is extremely high and widely variable. As a result of these variations, treatment concepts for combined sewer overflow require a different design approach than that used for conventional waste treatment facilities.

3.1 Combined Sewer Overflow Treatment Studies

The United States Environmental Protection Agency has sponsored several investigations on the treatment of combined sewer overflows. Field and Struzeski (6) report several of these studies which employ both biological and physical-chemical processes.

Among the biological treatment processes, activated sludge, contact stabilization, trickling filters and rotating biological contactors have been used to treat combined sewer storm flows. However, due to the highly variable quality and quantity of combined sewer overflows, physical-chemical treatment processes incorporating automated control techniques are more readily adaptable to providing efficient and reliable treatment.

Fine screens (microscreening) (5), flotation (10), high rate filtration (9), vortex swirl concentration (6), and activated carbon adsorption (15) have all been evaluated for BOD and suspended solids removal. Of these, microscreening and high rate filtration appear to provide the greatest removal efficiency for the least capital investment.

The E.P.A. has also funded studies on the disinfection of combined sewer overflows. Various disinfecting agents have been used, among which are chlorine (5), hypochlorite (12), chlorine dioxide (6), iodine

(6), and ozone (5). All were found to be effective in reducing the bacterial count, however, a pronounced temperature dependence was noted. Colder temperatures required more contact time to produce the same degree of kill for a given dosage. This effect will be important for disinfection of combined sewer overflows in Canadian conditions.

After reviewing the available literature, a treatment process based on a combination of fine screening and ozonation was judged to offer numerous advantages as opposed to other treatment systems for the abatement of pollution from combined sewer overflows.

3.2 Microscreening

Very Finely woven screens have been used successfully for several years to remove particulate matter from potable water supplies. One supplier of such a unit is Crane Canada Limited, which markets a rotating drum-like device with a stainless steel screen under the trademark "Micro-strainer" (3). It has also been used for tertiary treatment polishing of wastewater (3), (4).

More recently, (2), (5), work has been reported on the application of microscreening to the treatment of combined sewer overflows. Suspended solids removals ranging from 62 to 98 percent were achieved using a 23 micron screen. Corresponding BOD_5 removals were about 65 percent although some anomalous BOD_5 increases were obtained which were attributed to the exposure of more organic surface area caused by microscopic shear forces rupturing colloidal particles, as the filtrate passes through the screen. Throughput rates as high as 45 US gpm per square foot of screen area were used.

3.3 Ozonation

Traditionally, ozone has been limited to disinfection of municipal water supplies and treatment of toxic contaminants such as phenols and cyanides. These uses, however, have been restricted because of what was considered relatively high cost. With increasing efficiency of generation, ozone has been receiving attention as a method of (tertiary) treatment. Besides disinfection, it has been found (8), (14) that good colour, taste, and odour removal are obtained along with some BOD and

COD removal, depending on the ozone dosage used. In some cases reduction of turbidity has been observed as well. Dosages of ozone of 0.7 - 3.0 mg/l per mg/l COD in secondary effluent have given almost 60% reduction of COD at reasonable operating costs.

Recently, removal of heavy metals using ozone has been studied and found to be effective and economically feasible. A preliminary study for the E.P.A. (1) has shown that very high removal rates of iron from acid mine drainage can be achieved by ozone oxidation followed by lime neutralization, at a cost comparable to a similar system using air oxidation. In a recent Canadian study (11), ozone was found to greatly improve the efficiency of precipitation (by pH adjustment) of the following metals: aluminum, calcium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel and zinc. As the sole method of removal, ozonation of these metals to form insoluble oxides and hydroxides was reasonably effective (in most cases ~80% at pH 7.0). Of particular concern are lead and mercury, which are well known for their toxic effect on living organisms.

Ozone can be generated economically on a large scale from air or pure oxygen by the corona discharge method (14). Generation using pure oxygen is economical only if spent oxygen recycle is used, while air is usually used in a single pass system. Whether air or pure oxygen is used as an oxygen source for ozone generation depends on power costs, ozone requirements and oxygen losses through the system. Generally, for treatment facilities requiring large amounts of ozone, pure oxygen is used. Pure oxygen has the further advantage that a more concentrated ozone gas stream is produced.

Because the presence of water vapour significantly reduces the efficiency of ozone generation, generation from both air and recycled oxygen requires thorough drying to a dew-point of less than -60°F . The efficiency of ozone generation from recycled oxygen is also reduced by the presence of diluent gases such as nitrogen, and carbon monoxide. Hence some of the recycled oxygen stream is bled off to prevent build-up of diluent gases stripped from the wastewater being treated, and is replaced by pure oxygen.

3.4 Advantages of Microscreen-Ozone Treatment System

There are several advantages offered by the proposed combined sewer overflow treatment system. The process is readily adaptable to most overflow sites as an "in-pipe" treatment method. The grit and oil separator and microscreen are low head loss devices that could be placed in an enlarged in-line chamber cut into the existing drainage system. In many circumstances, the entire treatment system could be below ground level.

In addition, the system consists of relatively simple units which are currently available and have been proven to be reliable in long-term operation. No pumps are required to increase the hydraulic head of the runoff water as would be needed for such systems as porous media filtration, activated carbon adsorption or hydrocyclone treatment.

The use of ozone in the treatment system results in numerous performance and operational advantages. Ozone would be generated on-site, eliminating the necessity for transportation and handling of hazardous chemicals such as chlorine, chlorine dioxide or hypochlorite. In addition, ozone has the advantage of removing colour, BOD and COD from the effluent as well as acting as a powerful disinfectant.

The entire treatment system could be readily adapted for automatic operation in such a way that unattended start-up would result whenever an overflow occurred.

4. DESCRIPTION OF PILOT PLANT EQUIPMENT

The combined sewer overflow pilot treatment system as installed at the West Oakville Water Pollution Control Plant is illustrated schematically in Figure 1. The treatment plant included a coarse screen to remove rags and other large solid material that would hinder the operation of the fine screen. A V-notched weir was used subsequent to the feed pump to monitor the influent flowrate, and the upstream channel served as a small gravity separator for the removal of any readily settleable material. A microscreen provided suspended solids and BOD₅ removal and effluent samples from the fine screen were collected for subsequent batch ozonation in the Pollutech laboratory.

The pilot plant system utilized a Crane-Cochrane "Microstrainer"^{*}, 2½ feet in diameter by 2 feet long, the surface of which was covered by a woven stainless steel mesh with nominal apertures of 23 microns (Mark "O"). An isometric drawing of the Microstrainer in operation is shown in Figure 2.

During operation, the Microstrainer drum is submerged in the waste stream to approximately two-thirds of its diameter, giving a total submerged screen area of about 10.5 square feet for the particular unit used for this study. Raw waste enters through the upstream end of the drum and flows radially outward through the fine screen. Solids are entrapped on the inside of the mesh and the screened effluent is discharged from an overflow weir at the rear of the drum tank. Backwash jets mounted across the top of the drum wash the solids from the rotating screen into a collection trough inside the Microstrainer.

The accumulation of solids and the flow restriction due to the small area available through the 23 micron apertures results in a head loss across the fabric. The magnitude of the differential liquid level can be controlled, to some extent, by the speed of rotation of the drum. Increasing the rate of revolution will serve to expose more screen area per minute to the backwash jets, minimizing the head loss across the screen. The backwash flow and pressure can also be adjusted to provide optimum filtering conditions.

* Registered trademark, Crane Canada Ltd.

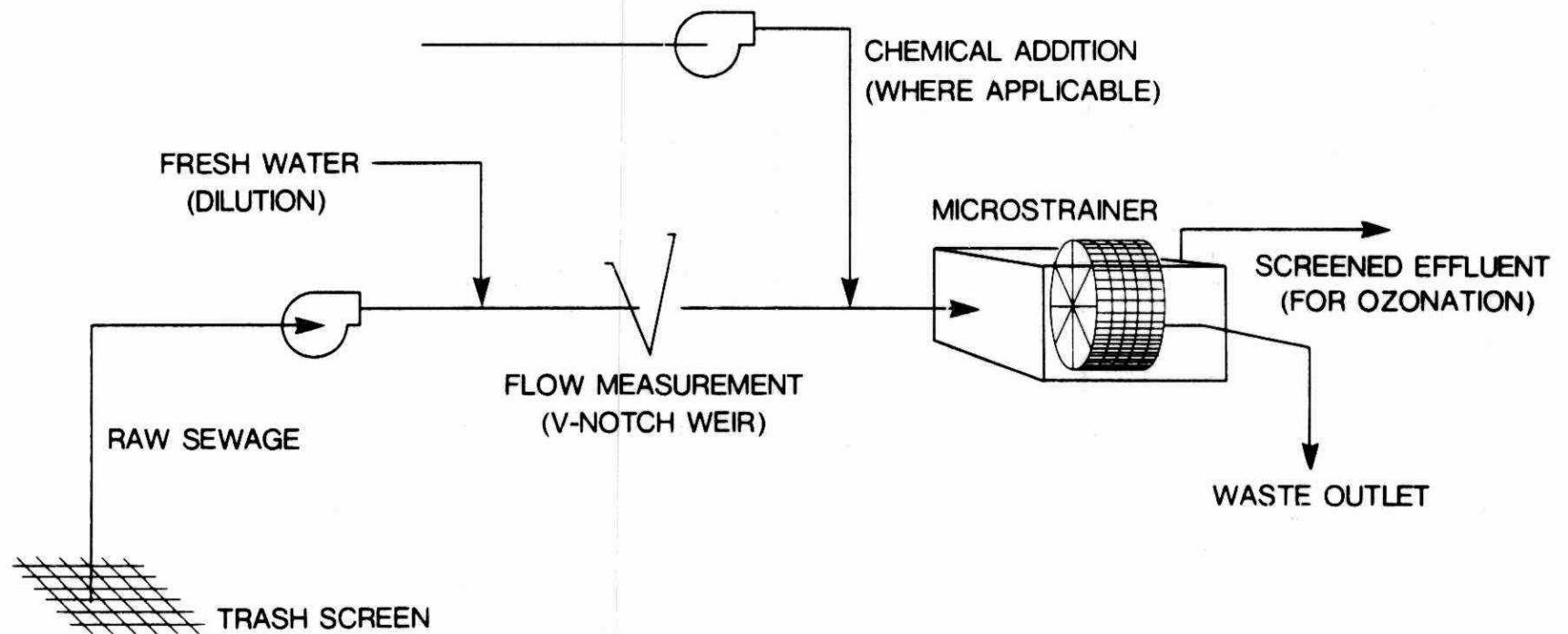


Figure 1 Schematic Representation of Microstrainer Installation

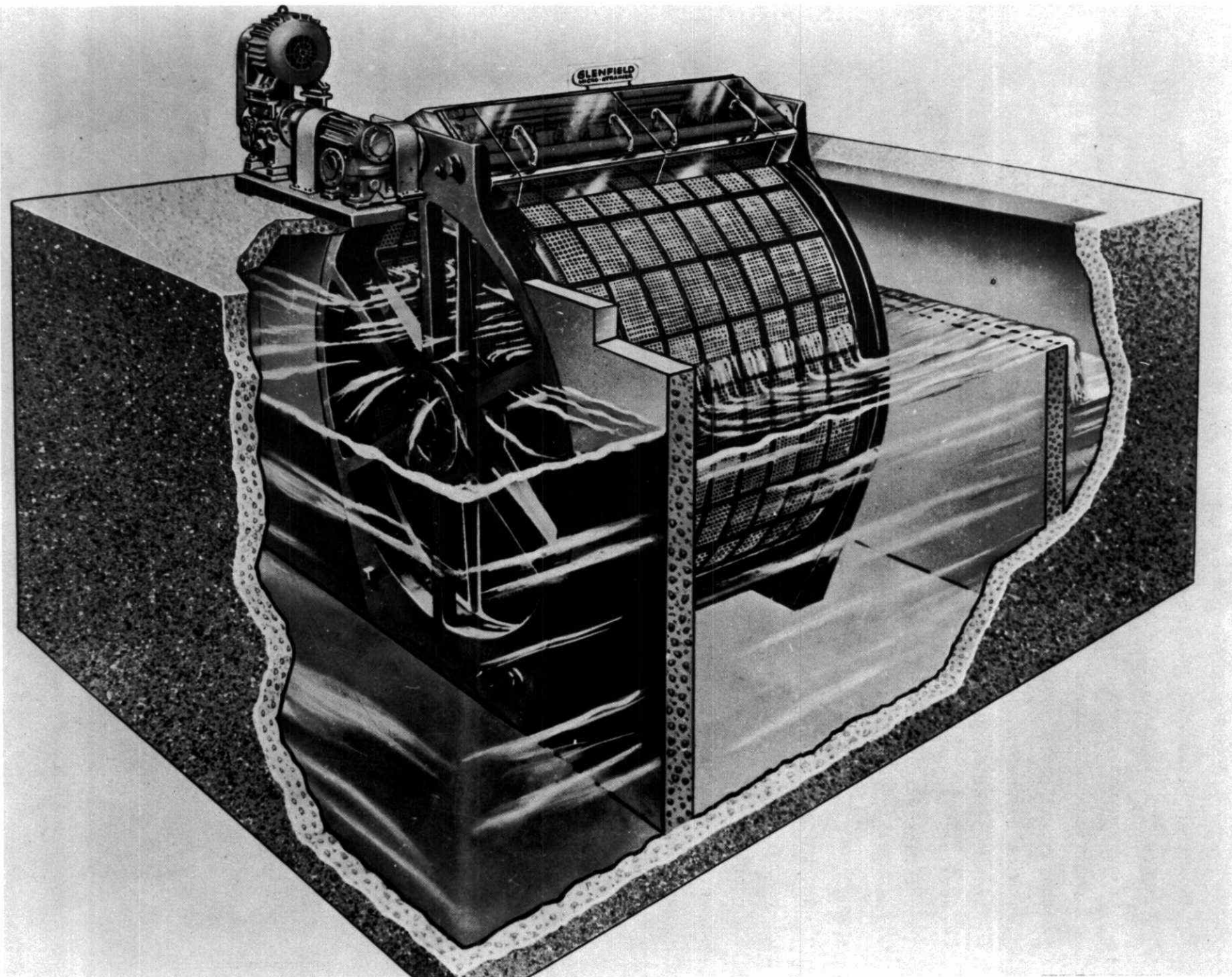


FIGURE 2. Isometric Drawing of a Microstrainer.

Source: Crane Canada Ltd., Environmental Systems Division, Rexdale, Ontario.

According to the manufacturer's specifications, optimum screening is attained when the head loss across the fabric is between 3 and 5 inches. Design hydraulic loading of the Microstrainer, according to Crane-Cochrane personnel, is 3 US gpm per square foot of submerged screen area, but the maximum loading of the unit will be dependent on the solid content and filterability of the waste stream. Previous studies have indicated that loadings as high as 45 US gpm/ft² are feasible for the treatment of combined sewer overflows; however, these throughputs were attained at a differential liquid level of up to 23 inches. The size of the Microstrainer used for this investigation precluded the use of hydraulic heads of this magnitude.

Ozone was produced from pure oxygen by a Model LG-2-L1 Corona Generator capable of delivering 250 grams of ozone per day. During the batch ozonation studies used to define the contaminant concentration profiles across the treatment system, 1800 ml samples of screened effluent were exposed to the entire ozone output of the generator for twenty minutes. However, when a continuous co-current contact chamber was used for subsequent studies, a large proportion of the ozone produced was wasted to atmosphere through a fume hood.

5. EXPERIMENTAL PROCEDURES

Following consultation with the Scientific Authority, the decision was made to use diluted raw sewage rather than actual combined sewer overflow as the feed to the microscreen pilot unit. This procedure allowed control of the sewage strength through dilution of the raw waste stream as well as facilitating daily operation of the unit regardless of climatic conditions.

In general, combined sewer overflows can be considered to be diluted sanitary sewage. However, there is an initial surge of high strength waste resulting from the first flush of the streets and sewers. Therefore, the effect of waste strength on the performance of the Microstrainer was evaluated by varying the degree of dilution of the raw sewage with unchlorinated freshwater. The degree of dilution was varied from 0 (undiluted raw sewage) to 200 percent (two parts freshwater to one part of raw sewage).

The combined sewage flowrate will also vary significantly during the storm period. The Microstrainer performance was, therefore, evaluated at hydraulic loadings varying from 1.5 US gpm/ft² to 6.0 US gpm/ft² (the design loading is 3.0 US gpm/ft²). Because of pump and drainage limitations associated with the pilot scale installation, the loading in excess of 3 US gpm/ft² was attained by blanking off half of the screen area.

The effect of chemical addition on the treatment efficiency was evaluated at design hydraulic loading and 50% dilution of the raw sewage. The chemical additives were injected into the overflow from the weir to provide the required rapid mixing. The less turbulent portion of the inlet chamber to the Microstrainer provided the degree of mixing necessary for flocculation of the particles.

Ferric chloride was chosen as the coagulant based on information obtained from Crane-Cochrane personnel with respect to their experience with various flocculating agents. Floc produced by the addition of ferric chloride to the screen influent was found to be less susceptible to shear on the Microstrainer mesh than floc produced by alum addition under similar operating conditions. Magnifloc 900N (American Cyanamid)

was selected as a flocculent aid based on the results of previous studies in the Pollutech laboratory with a number of polyelectrolytes in jar-testing on raw sewage for phosphorus removal. There are a large number of polyelectrolytes on the market; however, the evaluation of their relative performance was felt to be beyond the scope of this study. The optimum dosages of these chemicals were determined in preliminary jar testing on the diluted sewage.

The Microstrainer was operated at constant dilution and hydraulic loading for at least 1 1/2 hours under each set of conditions. The start-up procedure involved adjusting the flowrate of dilution water to the inlet weir at the pre-selected level. Raw sewage was then fed to the inlet weir at the rate giving the desired dilution and selected hydraulic loading. The microscreen drum and backwash pump were started and the drum speed adjusted to maintain a differential liquid level across the screen of between 3 and 5 inches. If a head of less than 5 inches could not be maintained, the differential liquid levels were minimized as much as possible for the experimental conditions.

The system was allowed to run for about thirty minutes until relatively stable conditions were attained in terms of differential head, flowrate, drum speed and backwash pressure. When the operating conditions had stabilized the sampling program was commenced.

The unit was operated at constant conditions for one hour and the concentration profiles across the screen were evaluated on manually-collected composite samples consisting of six grab samples taken at ten minute intervals from the influent and effluent streams and the backwash stream. A duplicate sample of the screened effluent was taken for batch ozonation due to the difficulties in obtaining identical oil and grease concentrations from two aliquots from the same sample container. The performance of the pilot plant was evaluated in terms of the BOD, total organic carbon, suspended solids, total phosphorus, total coliform count, oil and grease, and true colour concentration profiles.

After each one hour run, the raw sewage flow to the unit was stopped and the system flushed with freshwater. The Microstrainer was drained at the end of each run to prevent the accumulation of solids in the inlet chamber, drum tank and effluent chamber. The solids material

settled in the open channel upstream of the V-notched weir was also removed from the system between runs.

The effect of ozone on the contaminant concentration profile was evaluated by batch treatment of the duplicate screened samples. Based on discussions with the Scientific Authority, it was felt that this procedure would indicate the maximum removal which could be attained from the proposed treatment system. An 1800-ml sample was ozonated in a two litre graduated cylinder for 20 minutes. Ozone was dispersed through a fine diffusion stone to ensure that the treatment attained was not controlled by mass transfer limitations. The nominal dosage of ozone, based on the ozone capacity of the generator was 1675 mg/l; the amount of ozone which escaped unreacted from the liquid was not measured as the procedure was intended only to define the limits of the treatment system. Total oxygen flow to the ozone generator was maintained at 7.9 scfh.

The effect of ozonation on the screened effluent under more realistic operational conditions was evaluated in a continuous co-current contact chamber. The apparatus used for these studies is illustrated schematically in Figure 3. Screened effluent was pumped to the contact column using a peristaltic pump at a controlled rate to provide 5, 10 and 15 minutes of liquid retention in the unit. Ozone was fed to the unit through a fine diffusion stone at a measured rate to provide dosages of 10, 15 and 20 mg/l of ozone. Excess ozone was vented to the fume hood. The ozone removal efficiency was monitored in terms of the COD concentration of the column effluent at the various conditions.

As storm runoffs, particularly those resulting from snow-melts in urban areas, are known to contain a high concentration of lead contaminants from automotive exhausts, the effectiveness of ozonation for the precipitation of lead was evaluated using the same continuous co-current contact apparatus as used for the COD investigation. However, the low lead concentration of the West Oakville WPCP raw sewage made it necessary to artificially increase the lead content of a screened effluent sample by the addition of lead nitrate. The effect of ozone at various dosages and contact times was then evaluated.

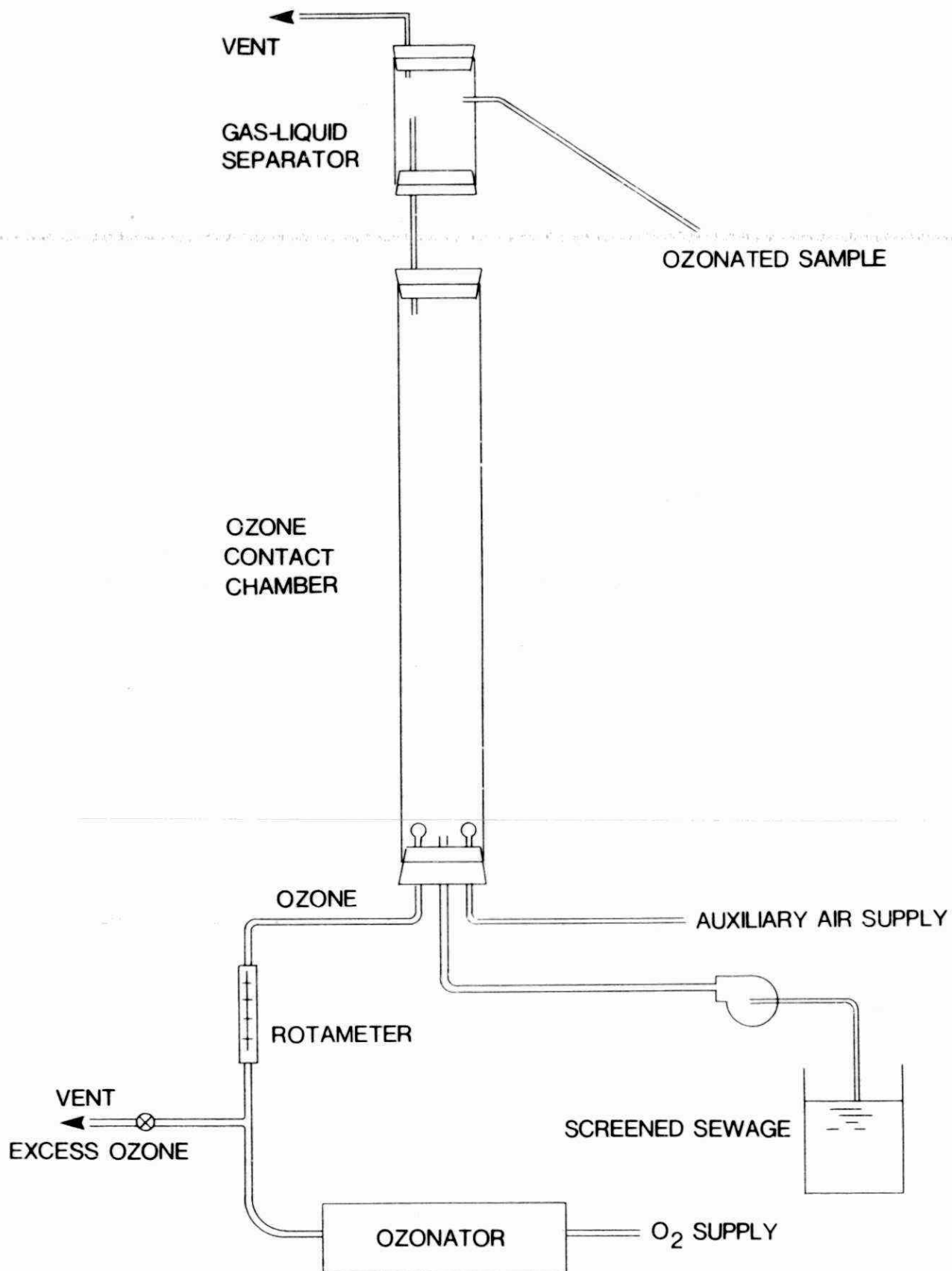


Figure 3 Schematic Representation of Ozone Contact Chamber

The soluble lead concentration of the screened effluent sample before ozone treatment was increased to 5 mg/l. Although this level is somewhat higher than normally experienced in storm-runoff, it allowed more accurate analytical estimation of the removal efficiency.

All analytical procedures were carried out according to Standard Methods for the Examination of Water and Wastewater (1971). The estimation of total coliform organism count was done by the membrane filtration technique. A Varian Techtron Model 1000 Atomic Adsorption Spectrophotometer was used for lead analysis and Beckman Model 915 Total Organic Carbon Analyzer for determination of the TOC concentration. Colour was determined on filtered samples using the Hach EL-ER kit against cobalt-platinum standards.

6. RESULTS

6.1 Operational Observations

Some difficulties were encountered during the initial setup and debugging of the pilot Microstrainer unit. The size of the unit (total weight 2300 lb) created problems in finding an accessible site for the study. Winter conditions during the study period excluded an outdoor location for the pilot plant equipment and the scope of the project precluded the construction of a heated building to allow flexibility in the choice of the test site. Some problems were encountered with raw sewage pumps and piping freezing during the runs. In addition, some minor problems were found in the actual operation of the Microstrainer, including a broken mechanical seal on the backwash pump.

No major operational problems were experienced with the pilot plant system following the initial setup period. However, the backwash heads required continuous surveillance as they tended to vibrate loose and would not provide adequate coverage of the drum area without readjustment. This problem could be alleviated with a better system of locknuts, making the unit dependable for automatic operation.

Despite the short retention time in the inlet box, sedimentation of sewage solids was evident. A heavy layer of primary sludge built up in the Microstrainer inlet chamber and frequently plugged the drain valves, preventing complete cleaning of the system between runs. These solids were not entrapped on the microscreen and, therefore, not removed in the backwash waste stream. There also appeared to be flocculation of solids in the effluent chamber, particularly in the runs involving chemical addition. A buildup of solids in this area and the aforementioned drainage problems resulted in some ambiguities in the suspended solids results. Problems of this nature may cause difficulties with in-stream automatic operation, unless the system is thoroughly cleaned between overflows. High flows could flush the settled solids through the system and overload the microscreen.

The Microstrainer was originally designed for the removal of algae and other suspended solids from potable water supplies. It has since been applied successfully as a tertiary treatment scheme for the

removal of suspended solids from the effluent from secondary waste treatment plants. However, for the treatment of wastes containing high concentrations of suspended solids such as encountered in combined sewer overflow, it may be necessary to redesign the drainage equipment to handle the higher solid loadings.

The differential head across the microscreen could not be maintained at less than four inches during any of the runs, despite adjustment of the drum speed to the maximum level. At design loading (3 US gpm/ft^2), the head loss varied from 4.5 to 7.0 inches increasing with the suspended solids content of the influent waste. The addition of polyelectrolyte to the sewage also appeared to increase the head loss across the screen. As expected, the differential head increased with the hydraulic loading, reaching a maximum of 7 inches during the run at 6 US gpm/ft^2 . According to the Microstrainer specifications, the maximum allowable differential head is 6 inches. It had been proposed to run the unit at loadings up to 30 US gpm/ft^2 but this was abandoned due to the excessive head losses encountered at lower flowrates.

6.2 Performance of Pilot Treatment System

The average overall removal efficiencies of the pilot scale Microstrainer - ozonation system for all of the conditions investigated are summarized in Table 1. The treatment system performance for all experimental conditions are also presented in the form of probability plots in Figures 4 to 10. This type of data presentation does not necessarily indicate the degree of contaminant removal which could be expected from each stage of the treatment system because the results were obtained under different operating conditions. However, the data are easy to visualize and ambiguities or random variations in operation are not reflected when the data are presented in this manner.

The results of the individual test runs are given in Tables 2 to 9, along with the experimental conditions with respect to degree of dilution, hydraulic loading and chemical dosage, if relevant. Specifically, Tables 2 to 5 refer to the runs evaluating the effect of sewage strength, as controlled by the degree of dilution on the Microstrainer performance. Tables 6 and 7 indicate the effect of variations of hydrau-

TABLE 1. AVERAGE OVERALL REMOVAL EFFICIENCY

<u>PARAMETER</u>	<u>PERCENT REMOVAL</u>
Total BOD ₅	67
Total Organic Carbon	28
Suspended Solids	40
Total Phosphorus	26
Oil and Grease	50
True Colour	64
Total Coliforms	>99.9

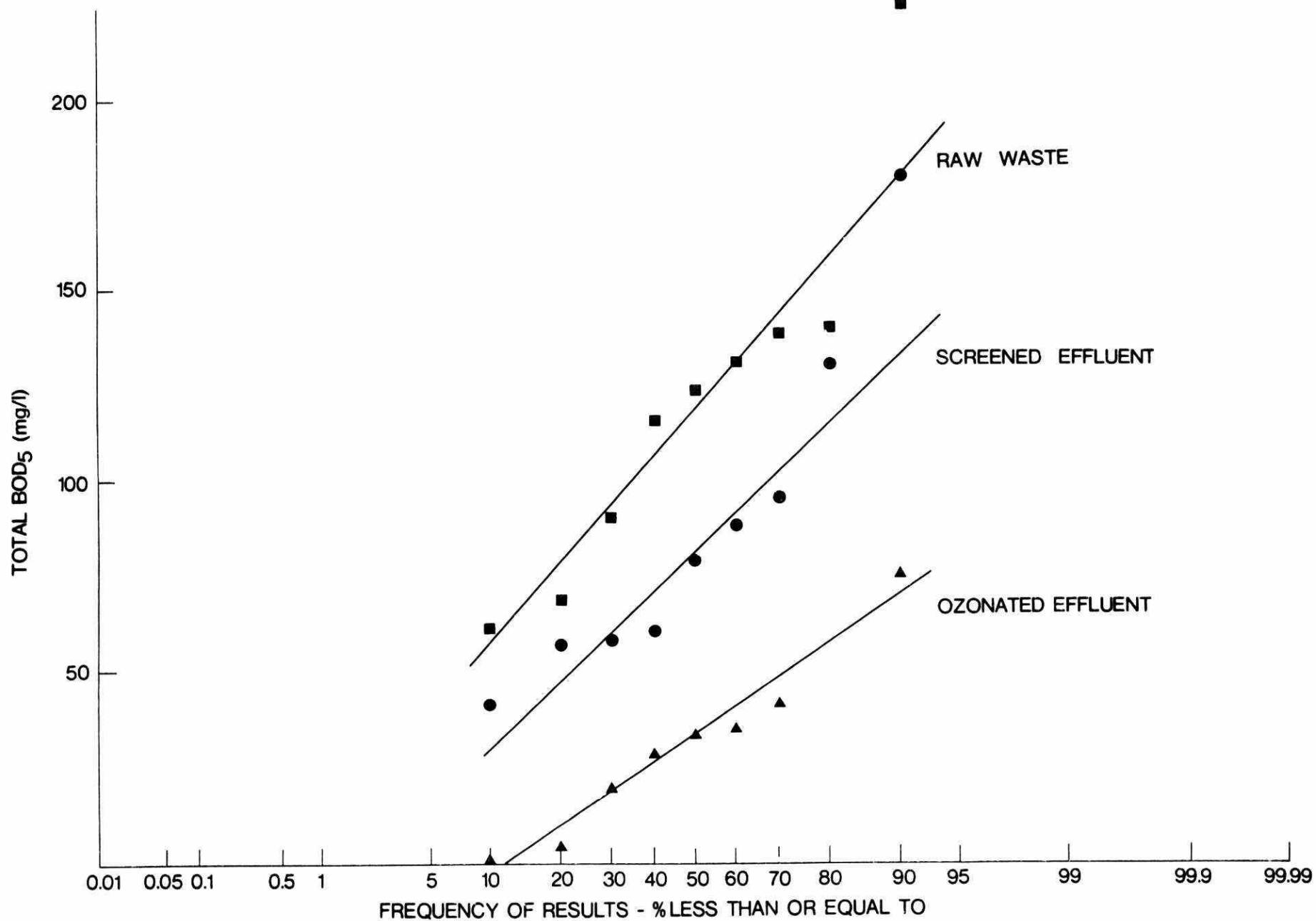


Figure 4 Treatment System Performance; BOD₅ Concentration Profile

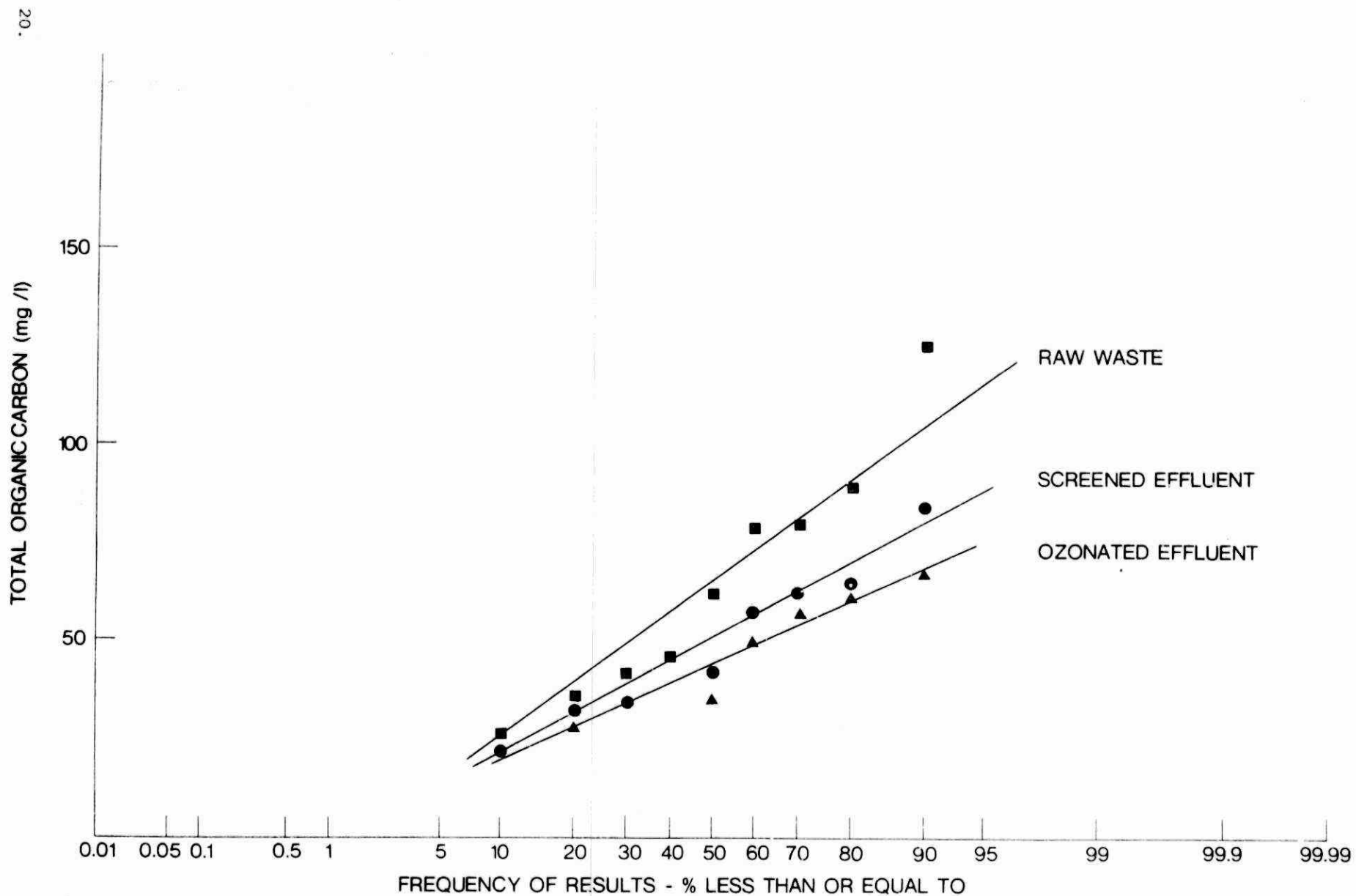


Figure 5 Treatment System Performance; Total Organic Carbon Concentration Profile

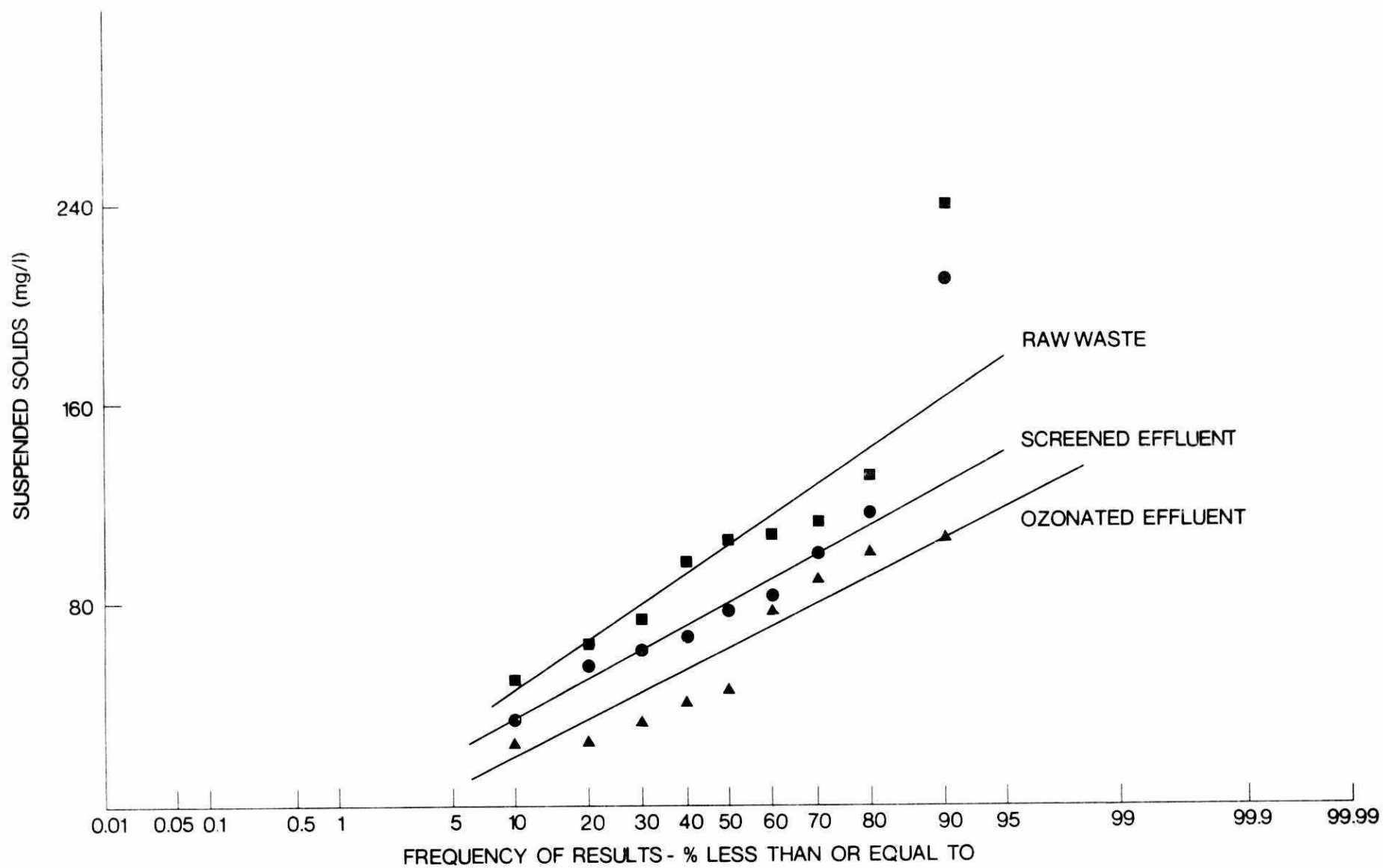


Figure 6 Treatment System Performance; Suspended Solids Concentration Profile

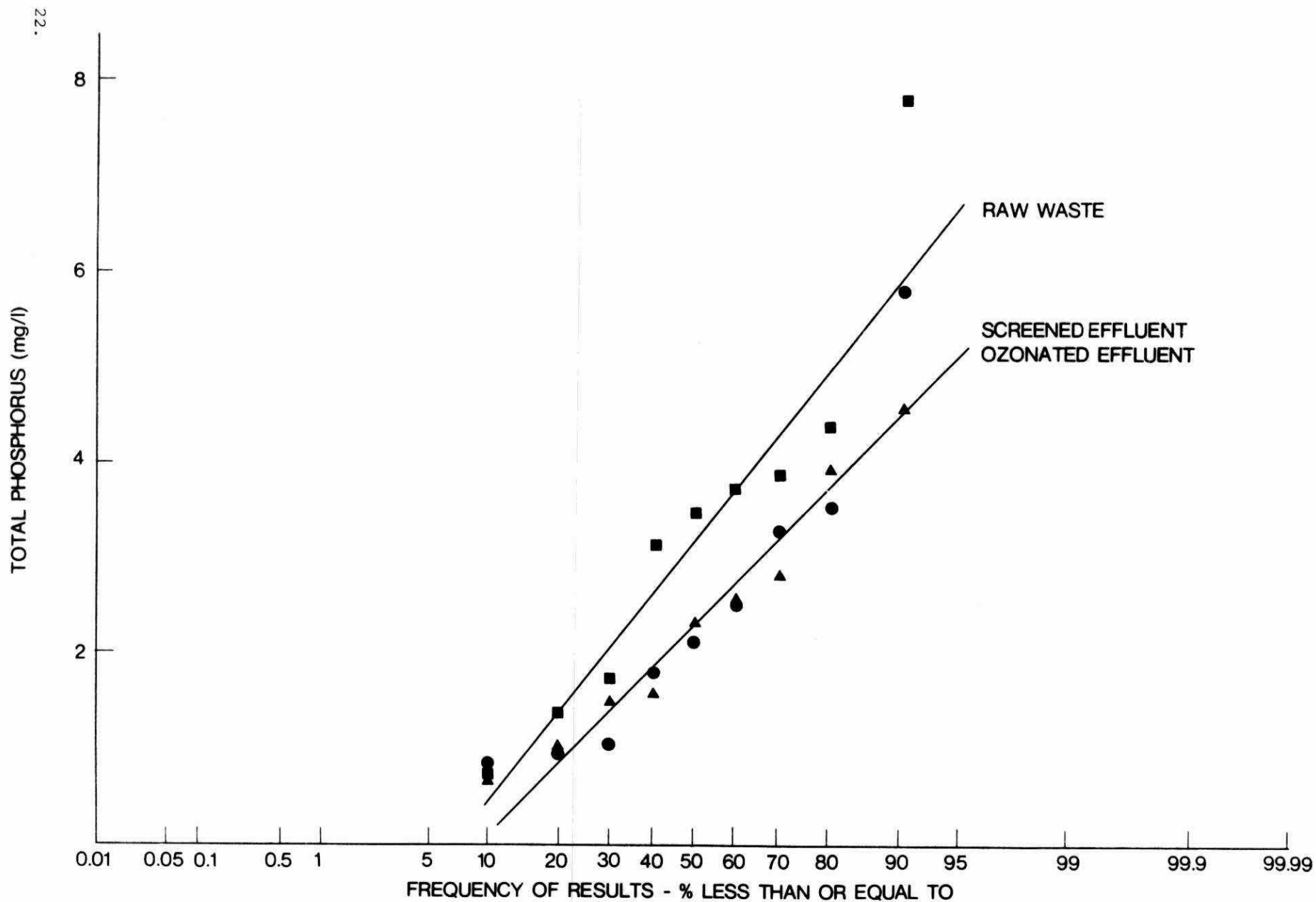


Figure 7 Treatment System Performance ; Total Phosphorus Concentration Profile

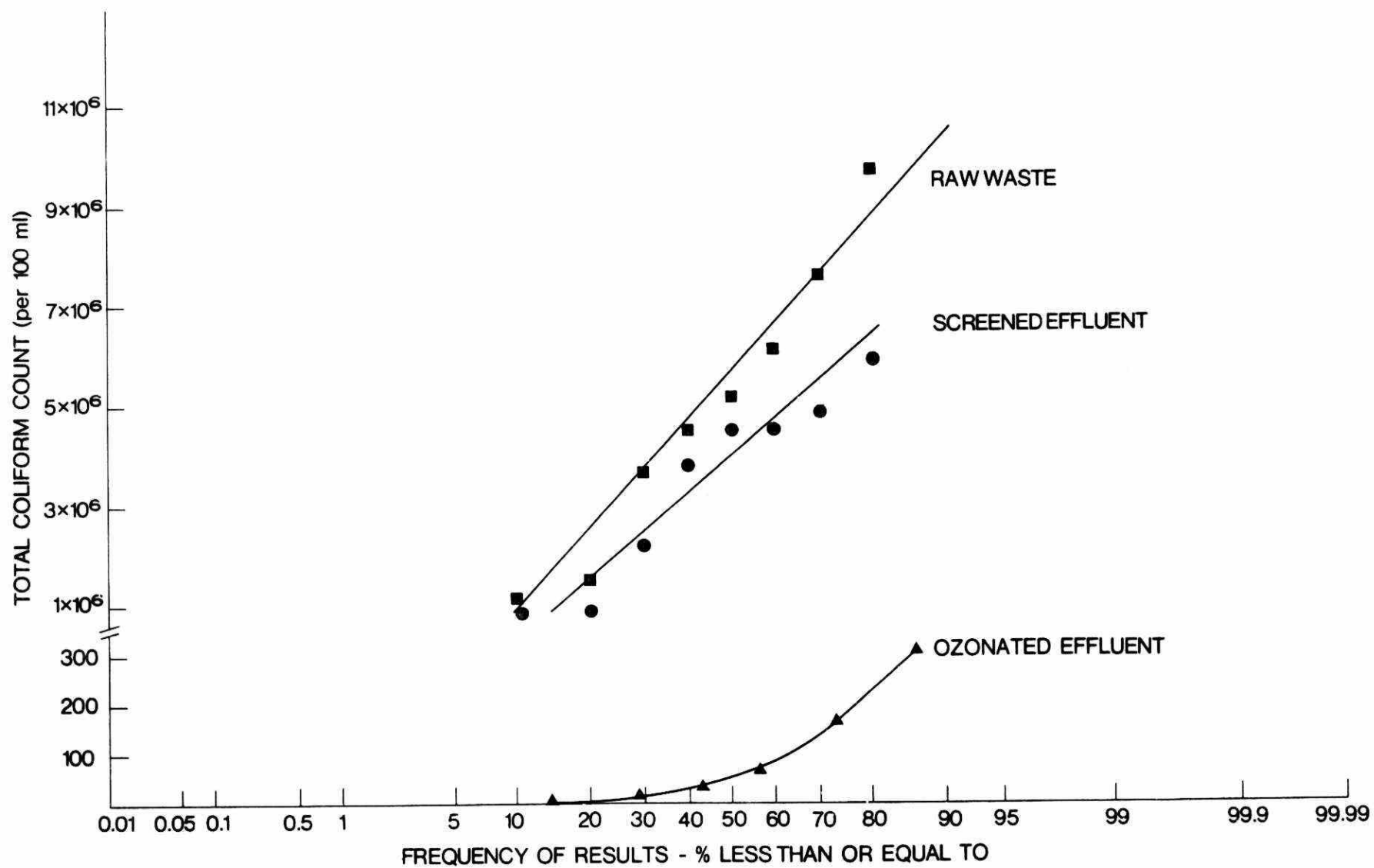


Figure 8 Treatment System Performance; Total Coliform Count Profile

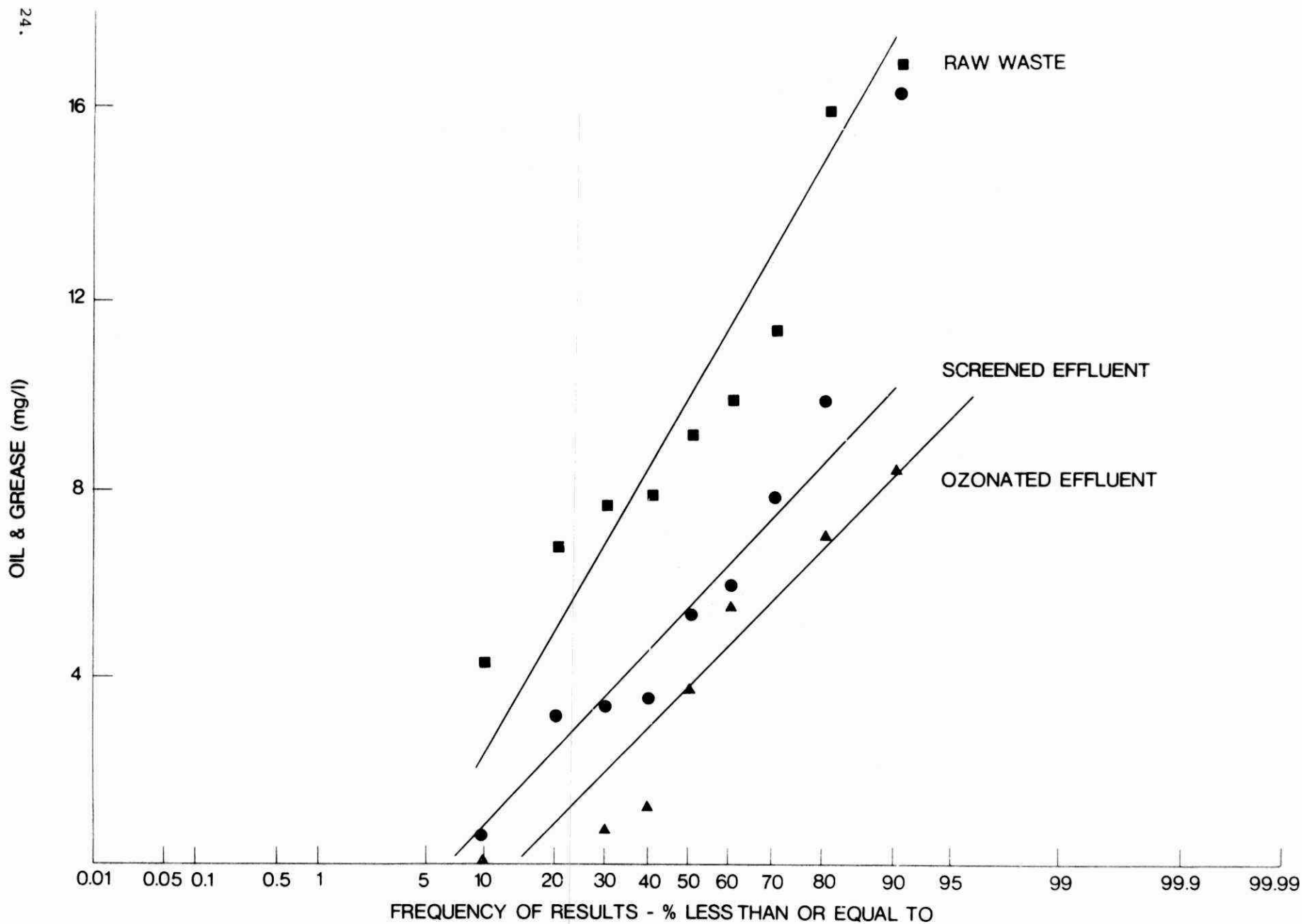


Figure 9 Treatment System Performance; Oil and Grease Concentration Profile

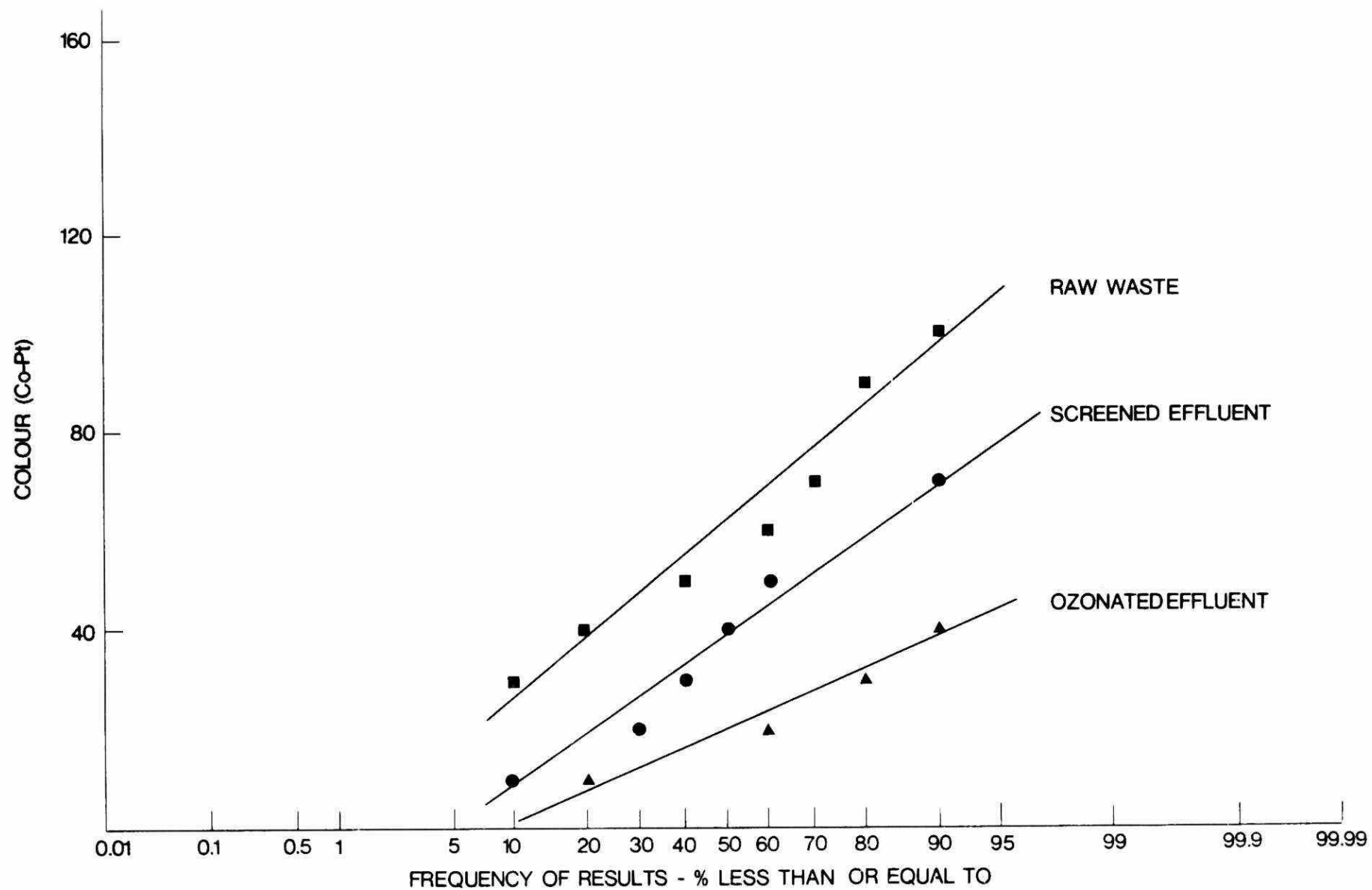


Figure 10 Treatment System Performance; Colour Profile

lic loading on the treatment efficiency. Tables 8, 9 and 10 present the results of chemical addition on the performance of the unit.

Examination of these data indicates some anomalies with respect to the anticipated downward trend of contaminant concentrations across the treatment system. Lack of precision in the analytical technique for measurement of the oil and grease concentration at the very low levels encountered in the sewage may have contributed in some degree to the variation in these results. The suspended solids and oil and grease results were probably also affected by the buildup of solids in the Microstrainer effluent chamber. The inability of the TOC injection syringe to handle solids material larger than the needle caused relatively lower TOC results than would have been expected based on the corresponding BOD readings.

Bacteriological determinations of total coliform organism counts indicate both reductions and increases across the microscreen. Passage of the biological solids through the screen probably results in the breakdown of bacterial conglomerates into smaller clumps, resulting in an increase in the coliform count. This apparent increase in the bacterial concentration has been reported in the literature from similar studies on microstraining of combined sewer overflow (5).

Ozonation, as expected, resulted in a large reduction in the coliform counts. In the three initial runs (Tables 2, 3 and 4), the total coliform counts are reported as less than 1000 cells per 100 ml as the disinfection efficiency of the batch ozonation was much higher than anticipated. In the subsequent coliform determination, the dilutions were corrected to allow accurate counting of the coliform colonies produced following incubation.

6.3 Effect of Sewage Strength on the Performance of the Microstrainer

The effect of sewage strength on the performance of the Microstrainer is summarized in Table 11. The results indicate that generally the removal efficiency in terms of all parameters is significantly reduced as the strength of the sewage increases.

TABLE 2. TREATMENT SYSTEM PERFORMANCE, RUN #1

Experimental Conditions:

Screen Hydraulic Loading	=	3 US gpm/ft ²
Sewage Flowrate	=	32 US gpm
Dilution Water Flowrate	=	0 US gpm
Chemical Added	=	None
Concentration	=	-
Ozone Contact Time	=	20 minutes
Nominal Ozone Concentration	=	1675 mg/l

PARAMETER	RAW INFLUENT	SCREENED EFFLUENT	OZONATED EFFLUENT
Total BOD ₅ (mg/l)	228	180	76
Total Organic Carbon (mg/l)	126	84	57
Suspended Solids (mg/l)	240	210	106
Total Phosphorus (mg/l)	7.80	5.85	4.60
Oil and Grease (mg/l)	16	16	7
Colour	100	70	30
Soluble Lead (mg/l)	< 1.00	-	-
Total Coliform (per 100 ml)	3,600,000	4,500,000	< 1,000
Soluble Phosphorus (mg/l)	-	-	-

Backwash Characteristics:

Flow (average)	=	2.0 US gpm
Pressure (average)	=	32 psig
Suspended Solids Content	=	229 mg/l

TABLE 3. TREATMENT SYSTEM PERFORMANCE, RUN #2

Experimental Conditions:

Screen Hydraulic Loading	=	3 US gpm/ft ²
Sewage Flowrate	=	21 US gpm
Dilution Water Flowrate	=	11 US gpm
Chemical Added	=	None
Concentration	=	-
Ozone Contact Time	=	20 minutes
Nominal Ozone Concentration	=	1675 mg/l

PARAMETER	RAW INFLUENT	SCREENED EFFLUENT	OZONATED EFFLUENT
Total BOD ₅ (mg/l)	138	78	33
Total Organic Carbon (mg/l)	89	57	49
Suspended Solids (mg/l)	112	68	41
Total Phosphorus (mg/l)	3.90	2.15	2.35
Oil and Grease (mg/l)	17	4	7
Colour	40	30	10
Soluble Lead (mg/l)	< 1.00	-	-
Total Coliform (per 100 ml)	6,100,000	4,500,000	< 1,000
Soluble Phosphorus (mg/l)	-	-	-

Backwash Characteristics:

Flow (average)	=	3.0 US gpm
Pressure (average)	=	29 psig
Suspended Solids Content	=	158 mg/l

TABLE 4. TREATMENT SYSTEM PERFORMANCE, RUN #3

Experimental Conditions:

Screen Hydraulic Loading	=	3 US gpm/ft ²
Sewage Flowrate	=	16 US gpm
Dilution Water Flowrate	=	16 US gpm
Chemical Added	=	None
Concentration	=	-
Ozone Contact Time	=	20 minutes
Nominal Ozone Concentration	=	1675 mg/l

PARAMETER	RAW INFLUENT	SCREENED EFFLUENT	OZONATED EFFLUENT
Total BOD ₅ (mg/l)	123	95	42
Total Organic Carbon(mg/l)	78	64	62
Suspended Solids (mg/l)	108	83	45
Total Phosphorus (mg/l)	3.15	2.55	2.85
Oil and Grease (mg/l)	11	6	0
Colour	60	50	20
Soluble Lead (mg/l)	1.50	< 1.00	< 1.00
Total Coliform (per 100 ml)	1,100,000	890,000	< 1,000
Soluble Phosphorus (mg/l)	-	-	-

Backwash Characteristics:

Flow (average)	=	2.0 US gpm
Pressure (average)	=	33 psig
Suspended Solids Content	=	132 mg/l

TABLE 5. TREATMENT SYSTEM PERFORMANCE, RUN #4

Experimental Conditions:

Screen Hydraulic Loading = 3 US gpm/ft²
 Sewage Flowrate = 11 US gpm
 Dilution Water Flowrate = 21 US gpm
 Chemical Added = None
 Concentration = -
 Ozone Contact Time = 20 minutes
 Nominal Ozone
 Concentration = 1675 mg/l

PARAMETER	RAW INFLUENT	SCREENED EFFLUENT	OZONATED EFFLUENT
Total BOD ₅ (mg/l)	90	42	4
Total Organic Carbon (mg/l)	27	22	22
Suspended Solids (mg/l)	64	32	23
Total Phosphorus (mg/l)	1.75	0.95	1.00
Oil and Grease (mg/l)	9	3	1
Colour	30	10	10
Soluble Lead (mg/l)	< 1.00	-	-
Total Coliform (per 100 ml)	1,470,000	890,000	14
Soluble Phosphorus (mg/l)	-	-	-

Backwash Characteristics:

Flow (average) = 1.8 US gpm
 Pressure (average) = 26 psig
 Suspended Solids Content = 63 mg/l

TABLE 6. TREATMENT SYSTEM PERFORMANCE, RUN # 5

Experimental Conditions:

Screen Hydraulic Loading = 1.5 US gpm/ft²
 Sewage Flowrate = 10.5 US gpm
 Dilution Water Flowrate = 5.3 US gpm
 Chemical Added = None
 Concentration = -
 Ozone Contact Time = 20 minutes
 Nominal Ozone
 Concentration = 1675 mg/l

PARAMETER	RAW INFLUENT	SCREENED EFFLUENT	OZONATED EFFLUENT
Total BOD ₅ (mg/l)	131	57	1
Total Organic Carbon (mg/l)	62	37	28
Suspended Solids (mg/l)	131	61	24
Total Phosphorus (mg/l)	4.40	1.80	1.50
Oil and Grease (mg/l)	11	1	0
Colour	50	40	20
Soluble Lead (mg/l)	<1.00	-	-
Total Coliform (per 100 ml)	5,100,000	2,200,000	5
Soluble Phosphorus (mg/l)	-	-	-

Backwash Characteristics:

Flow (average) = 1.7 US gpm
 Pressure (average) = 31 psig
 Suspended Solids Content = 102 mg/l

TABLE 7. TREATMENT SYSTEM PERFORMANCE, RUN #6

Experimental Conditions:

Screen Hydraulic Loading = 6.0 US gpm/ft²
 Sewage Flowrate = 21 US gpm
 Dilution Water Flowrate = 11 US gpm
 Chemical Added = None
 Concentration = -
 Ozone Contact Time = 20 minutes
 Nominal Ozone
 Concentration = 1675 mg/l

PARAMETER	RAW INFLUENT	SCREENED EFFLUENT	OZONATED EFFLUENT
Total BOD ₅ (mg/l)	61	58	28
Total Organic Carbon (mg/l)	42	42	25
Suspended Solids (mg/l)	50	55	32
Total Phosphorus (mg/l)	0.75	0.80	0.70
Oil and Grease (mg/l)	8	8	1
Colour	90	70	40
Soluble Lead (mg/l)	< 1.00	-	-
Total Coliform (per 100 ml)	7,600,000	4,800,000	310
Soluble Phosphorus (mg/l)	-	-	-

Backwash Characteristics:

Flow (average) = 1.7 US gpm
 Pressure (average) = 31 psig
 Suspended Solids Content = 53 mg/l

TABLE 8. TREATMENT SYSTEM PERFORMANCE, RUN #7

Experimental Conditions:

Screen Hydraulic Loading	=	3.0 US gpm/ft ²
Sewage Flowrate	=	21 US gpm
Dilution Water Flowrate	=	11 US gpm
Chemical Added	=	Ferric Chloride
Concentration	=	25 mg/l Fe ⁺³
Ozone Contact Time	=	20 minutes
Nominal Ozone Concentration	=	1675 mg/l

PARAMETER	RAW INFLUENT	SCREENED EFFLUENT	OZONATED EFFLUENT
Total BOD ₅ (mg/l)	115	88	35
Total Organic Carbon (mg/l)	46	42	35
Suspended Solids (mg/l)	74	77	90
Total Phosphorus (mg/l)	3.50	3.30	2.60
Oil and Grease (mg/l)	8	3	9
Colour	60	20	20
Soluble Lead (mg/l)	< 1.00	-	-
Total Coliform (per 100 ml)	10,600,000	3,800,000	60
Soluble Phosphorus (mg/l)	2.65	2.10	-

Backwash Characteristics:

Flow (average)	=	2.7 US gpm
Pressure (average)	=	31 psig
Suspended Solids Content	=	160 mg/l

TABLE 9. TREATMENT SYSTEM PERFORMANCE, RUN #8

Experimental Conditions:

Screen Hydraulic Loading	=	3.0 US gpm/ft ²
Sewage Flowrate	=	21 US gpm
Dilution Water Flowrate	=	11 US gpm
Chemical Added	=	Ferric Chloride & Magnifloc 900N (American Cyanamid)
Concentration	=	10 mg/l Fe ⁺³ , 0.5 mg/l Magnifloc
Ozone Contact Time	=	20 minutes
Nominal Ozone Concentration	=	1675 mg/l

PARAMETER	RAW INFLUENT	SCREENED EFFLUENT	OZONATED EFFLUENT
Total BOD ₅ (mg/l)	68	60	20
Total Organic Carbon (mg/l)	36	35	35
Suspended Solids (mg/l)	106	114	78
Total Phosphorus (mg/l)	1.40	1.05	1.60
Oil and Grease (mg/l)	4	5	4
Colour	50	20	20
Soluble Lead (mg/l)	< 1.00	-	-
Total Coliform (per 100 ml)	4,500,000	5,900,000	34
Soluble Phosphorus (mg/l)	0.55	0.15	-

Backwash Characteristics:

Flow (average)	=	2.2 US gpm
Pressure (average)	=	30 psig
Suspended Solids Content	=	126 mg/l

TABLE 10. TREATMENT SYSTEM PERFORMANCE, RUN #9

Experimental Conditions:

Screen Hydraulic Loading	=	3.0 US gpm/ft ²
Sewage Flowrate	=	21 US gpm
Dilution Water Flowrate	=	11 US gpm
Chemical Added	=	Magnifloc 900N
Concentration	=	0.5 mg/l
Ozone Contact Time	=	20 minutes
Nominal Ozone Concentration	=	1675 mg/l

PARAMETER	RAW INFLUENT	SCREENED EFFLUENT	OZONATED EFFLUENT
Total BOD ₅ (mg/l)	140	130	76
Total Organic Carbon (mg/l)	79	62	67
Suspended Solids (mg/l)	96	100	102
Total Phosphorus (mg/l)	3.75	3.55	3.95
Oil and Grease (mg/l)	7	10	6
Colour	70	70	30
Soluble Lead (mg/l)	< 1.00	-	-
Total Coliform (per 100 ml)	9,700,000	10,700,000	170
Soluble Phosphorus (mg/l)	-	-	-

Backwash Characteristics:

Flow (average)	=	2.5 US gpm
Pressure (average)	=	30 psig
Suspended Solids Content	=	67 mg/l

Flow of the waste through the fine filter mesh is caused by the differential liquid levels between the inside and the outside of the drum. As solids build up on the Microstrainer fabric, the number and size of clear apertures decreases and the liquid flow through the apertures increases. Both phenomena act to produce a higher differential liquid level across the screen. The greater hydraulic forces on the particles will tend to force the compressible solid material in the waste through the fine openings. Higher shear forces created by the higher flow rates through the constricted apertures will tend to fracture the organic solids and wash them through the mesh. The backwash heads are designed to remove the solids to prevent blinding of the filtration media; however, at high solids loadings, the system can become overloaded, resulting in a higher solids concentration in the effluent than would be expected under optimum operating conditions.

A differential head in excess of the manufacturer's recommended maximum of 6 inches across the screen was experienced when undiluted sewage was fed to the system, as compared to an average differential liquid level of only 4.5 inches at the highest dilution of the new sewage. During all of the runs, the drum rotational speed was maintained at the maximum rate in order to minimize the head loss as much as possible.

6.4 Effect of Hydraulic Loading on the Performance of the Microstrainer

The performance of the Microstrainer at different hydraulic loadings and 50 percent dilution of the raw sewage (2 parts of raw sewage and 1 part of freshwater) is summarized in Table 12. The overall trend of the results indicates a decline in the removal efficiency at higher hydraulic loadings.

Higher influent flow rates result in higher solids loadings of the screen. Therefore, the phenomena described in the previous section will act to increase the hydraulic and the shear forces on the solids present in the waste. This is compounded by the increased flow rates through the mesh due to the higher feed rate to the system. The result will be a decrease in the quality of the effluent due to the previously described compression and fracture of the waste solids.

TABLE 11. EFFECT OF SEWAGE STRENGTH ON MICROSTRAINER PERFORMANCE
(Hydraulic Loading = 3 US gpm/ft²)

PARAMETER	% Dilution of Sewage											
	0			50			100			200		
	INFLUENT	EFFLUENT	% REMOVAL	INFLUENT	EFFLUENT	% REMOVAL	INFLUENT	EFFLUENT	% REMOVAL	INFLUENT	EFFLUENT	% REMOVAL
Total BOD ₅ (mg/l)	228	180	21	138	78	36	123	95	23	90	42	53
Total Organic Carbon (mg/l)	126	84	33	89	57	36	78	64	18	27	22	18
Suspended Solids (mg/l)	240	210	13	112	68	39	108	83	23	64	32	50
Total Phosphorus (mg/l)	7.80	5.85	25	3.90	2.15	47	3.15	2.55	16	1.75	0.95	45
Oil & Grease (mg/l)	16	16	-	17	4	77	11	6	45	9	3	67
Total Coliform per 100 ml	3.60 x 10 ⁶	4.50 x 10 ⁶	-	6.10 x 10 ⁶	4.50 x 10 ⁶	37	1.10 x 10 ⁶	0.89 x 10 ⁶	19	1.47 x 10 ⁶	0.89 x 10 ⁶	39

TABLE 12. EFFECT OF HYDRAULIC LOADING ON MICROTRAINER PERFORMANCE
(50 percent dilution of raw sewage)

PARAMETER	LOADING								
	1.5 US gpm/ft ²			3.0 US gpm/ft ²			6.0 US gpm/ft ²		
	INFLUENT	EFFLUENT	% REMOVAL	INFLUENT	EFFLUENT	% REMOVAL	INFLUENT	EFFLUENT	% REMOVAL
Total BOD ₅ (mg/l)	131	57	57	138	78	36	61	58	5
Total Organic Carbon (mg/l)	62	37	40	89	57	36	42	42	0
Suspended Solids (mg/l)	131	61	53	112	68	39	50	55	-
Total Phos- phorus (mg/l)	440	1.80	59	3.90	2.15	47	0.75	0.80	-
Oil & Grease (mg/l)	11	1	91	17	3	82	8	8	-
Total Coli- form per 100 ml	5.10×10^6	2.20×10^6	57	6.10×10^6	4.50×10^6	26	7.60×10^6	4.80×10^6	37

The differential head across the screen increased proportionately to the hydraulic loading, being a minimum at a loading of 1.5 US gpm/ft² and increasing to a maximum at a loading of 6.0 US gpm/ft². At the highest hydraulic loading, the head loss exceeded the manufacturer's specified limits of 6 inches. It had been planned to evaluate the performance of the unit at still higher hydraulic loadings but this phase of the study was abandoned.

6.5 Effect of Chemical Addition on the Performance of the Microstrainer

Based on the results of jar studies carried out in the Pollutech laboratory and information obtained from Crane-Cochrane personnel with respect to the relative strength of alum and ferric chloride floc, only ferric chloride and Magnifloc 900N were evaluated for chemical treatment of the influent to the Microstrainer. The chemical dosages of the chemicals individually and in combination were determined by preliminary jar tests and the results are given in Table 13.

The effect of chemical addition on the performance of the Microstrainer was evaluated at the design hydraulic loading of 3 US gpm/ft² and a dilution of the raw sewage by 50 percent. The results are summarized in Table 14.

The soluble phosphorus results, as given in Tables 8 and 9, indicate that some precipitation did occur following the addition of ferric chloride. However, the removal in terms of total phosphorus was low. The turbulence created by the revolving drum appeared to break up the floc particles. Well-developed floc were evident in the inlet chamber of the microscreen, and also in the effluent chamber. The shear forces resulting from the high solid loading and the hydrostatic forces created by the high differential head experienced during these runs probably contributed to the fracture of the flocculent particles. It is also possible that optimum mixing conditions for floc growth were not provided by the system. No attempt was made during this study to optimize the point of chemical addition.

TABLE 13. OPTIMIZATION OF CHEMICAL DOSAGE
(Jar Test Results)

Initial Phosphorus Concentration = 5.40 mg/l

PRECIPITANT	DOSAGE (mg/l)	COAGULANT	DOSAGE (mg/l)	FINAL PHOSPHORUS CONCENTRATION (mg/l)	% REMOVAL
Fe ⁺³	10	None	-	0.99	81.6
Fe ⁺³	15	None	-	0.47	91.2
Fe ⁺³	25	None	-	0.20	96.2
Al ⁺³	5	None	-	3.70	31.4
Al ⁺³	10	None	-	2.08	61.5
Al ⁺³	15	None	-	0.60	88.9
Fe ⁺³	10	Magnifloc 900N	0.2	0.25	95.3
Fe ⁺³	10	Magnifloc 900N	0.5	0.24	95.5
Fe ⁺³	10	Magnifloc 900N	1.0	0.22	96.0
None	-	Magnifloc 900N	0.5	3.95	26.8
None	-	Magnifloc 900N	1.0	3.95	26.8
None	-	Magnifloc 900N	5.0	3.95	26.8

TABLE 14. EFFECT OF CHEMICAL ADDITION ON MICROSTRAINER PERFORMANCE
 (Hydraulic Loading = 3 US gpm/ft²
 50 percent dilution of raw sewage)

PARAMETER	CHEMICAL ADDITION											
	NONE			FERRIC CHLORIDE 25 mg/l Fe ³⁺			MAGNIFLOC 900N 0.5 mg/l			10 mg/l Fe ³⁺ and 0.5 mg/l Magnifloc 900N		
	INFLUENT	EFFLUENT	% REMOVAL	INFLUENT	EFFLUENT	% REMOVAL	INFLUENT	EFFLUENT	% REMOVAL	INFLUENT	EFFLUENT	% REMOVAL
Total BOD ₅ (mg/l)	138	78	36	115	88	23	140	130	7	68	60	-
Total Organic Carbon (mg/l)	89	57	36	46	42	9	79	62	22	36	35	3
Suspended Solids (mg/l)	112	68	39	74	77	-	96	100	-	106	114	-
Total Phosphorus (mg/l)	3.90	2.15	47	3.50	3.30	9	3.75	3.55	5	1.40	1.05	25
Oil & Grease (mg/l)	17	3	82	8	3	63	7	10	-	4	5	-
Total Coliform per 100 ml	6.10 x 10 ⁶	4.50 x 10 ⁶	37	10.6 x 10 ⁶	3.80 x 10 ⁶	63	9.70 x 10 ⁶	10.7 x 10 ⁶	-	4.50 x 10 ⁶	5.90 x 10 ⁶	-

6.6 Results of Ozonation Studies

The concentration profiles, in terms of all measured parameters after microscreening and batch ozonation of the simulated combined overflow, are given in Tables 2 and 10 and illustrated in Figures 4 to 10. The data indicate that the batch ozonation of the screened effluent results in a significant reduction in all contaminant concentrations except total phosphorus. Most significantly, the total coliform concentration was reduced by greater than 99.9 percent. It should be emphasized, however, that this degree of treatment will result in maximum removal of contaminants from the waste.

Figure 6 indicates that a significant reduction in the suspended solids concentration resulted following ozonation of the screened sample. It was suspected that a flotation mechanism was chiefly responsible for the decrease of the suspended solids content; however, when a sample was subjected to ozone as well as oxygen, the results, as summarized in Table 15, did not support this assumption.

In order to evaluate the effectiveness of ozone under realistic operational conditions of continuous co-current contact using the apparatus illustrated in Figure 3, screened effluent samples were dosed with different concentrations at various contact times. The reduction of COD in a screened effluent sample at various ozone dosages and contact times is summarized in Table 16. As expected, the residual COD concentration decreased at higher ozone dosages and with longer contact times. The maximum COD removal at 20 mg/l ozone and 15 minutes contact time was 46 percent.

Heavy metal contamination of stormwater runoff, such as lead resulting from automotive exhausts, is a particular concern of regulatory agencies. Because of the low lead concentrations in the West Oakville raw sewage, the effect of the treatment system in terms of lead removal could not be evaluated. Therefore, a screened effluent sample was spiked with a soluble lead salt and the effect of ozone evaluated in a manner similar to that used in the COD removal investigation. As shown in Table 17, the maximum lead precipitation obtained was 35 percent at 20 mg/l of ozone and 15 minutes contact time.

TABLE 15 EFFECT OF OZONE ON REMOVAL OF SUSPENDED SOLIDS

TREATMENT	SUSPENDED SOLIDS (mg/l)
None	63
Ozonation: O ₃ level = 10.4 g/hr Gas flow = 7.9 scfh Contact time = 20 min.	39
Oxygenation: Gas flow = 7.9 scfh Contact time = 20 min.	54

TABLE 16. EFFECT OF OZONE DOSAGE AND CONTACT TIME
ON COD REMOVAL

CONTACT TIME (min.)	OZONE DOSAGE (mg/l)	COD CONCENTRATION (mg/l)
5	10	115
5	20	107
10	10	91
10	20	86
15	10	74
15	20	70

Initial COD Concentration = 130 mg/l

TABLE 17. EFFECT OF OZONE DOSAGE AND CONTACT TIME
 ON LEAD REMOVAL

CONTACT TIME (min.)	OZONE DOSAGE (mg/l)	LEAD CONCENTRATION (mg/l)
5	10	4.40
5	20	4.25
10	10	4.00
10	20	3.95
15	10	3.65
15	20	3.55

Initial Soluble Lead Concentration = 5.00 mg/l

7. ECONOMIC EVALUATION OF THE TREATMENT SYSTEM

The results of the study using diluted raw sewage indicate that hydraulic loadings above the design rate of 3 US gpm/ft² produce a serious deterioration in the performance of the Microstrainer. Therefore, preliminary capital cost estimates for the Microstrainer equipment have been prepared based on the design hydraulic loading. Table 18 summarizes the approximate capital costs of Microstrainers in the various standard sizes, along with the design throughput of the unit. As indicated, the maximum flowrate possible is 707 US gpm and the treatment of combined sewer overflows at higher loadings would, therefore, require a number of similar units or the custom construction of a larger unit.

Ozonation cost estimates were based on linear interpolations of the data presented in (19). The costs were based on airfeed to the ozone generator and reflect 1972 prices. The actual ozone dosage required was not precisely established by this study. Therefore, costs estimates were based on 10 and 20 mg/l ozone and the calculations indicate a capital cost of \$15,000 to \$29,000 per 1000 US gpm at the respective dosages.

Figures 11 and 12 illustrate the approximate capital cost for microscreening and ozonation facilities, respectively, for various combined sewer overflow flowrates.

The economics of scale indicate that at a screening throughput rate of 3 US gpm/ft², the Microstrainer capital cost decreases from \$100,000 per 1000 US gpm to about \$90,000 per 100 US gpm as the design capacity of the installation increases from 1000 US gpm to 10,000 US gpm. Likewise for the ozonator at a dosage of 20 mg/l ozone, the capital cost decreases from about \$29,000 per 1000 US gpm to about \$22,000 per 1000 US gpm as the design capacity of the installation increases from 1000 US gpm to 10,000 US gpm.

Figure 13 shows the total equipment cost for various design capacities. For a screening throughput rate of 3 US gpm and an ozone dosage of 20 mg/l, the equipment costs decrease from about \$128,000 to \$113,000 per 1000 US gpm as the design capacity of the system increases from 1000 to 10,000 US gpm. These cost estimates reflect approximate equipment costs only and do not reflect land, installation, engineering or "plant" facilities which will vary depending upon the circumstances of the specific sewer overflow designated for treatment.

TABLE 18. COSTS AND CAPACITIES OF MICROTRAINERS^a

MICROTRAINER SIZE (DIA. x L, ft)	TANK DIMENSIONS (W x H x L, ft)	APPROXIMATE COST ^b (\$)	DESIGN FLOWRATE ^c (US gpm)
5 x 1	5.5 x 8 x 6	20,000	35
5 x 3	5.8 x 9 x 14	32,000	106
7.5 x 5	7 x 11 x 16	34,000	265
10. x 10	10.2 x 14 x 22	67,000	707

a Microstrainers equipped with "Mark O" fabric (23 micron)

b Includes motor, continuous wash and backwash hopper for all sizes and tank for all sizes except the 10 x 10 unit. (1974 figures)

c Based on 3 US gpm/ft² submerged area and average submergence of 75%.

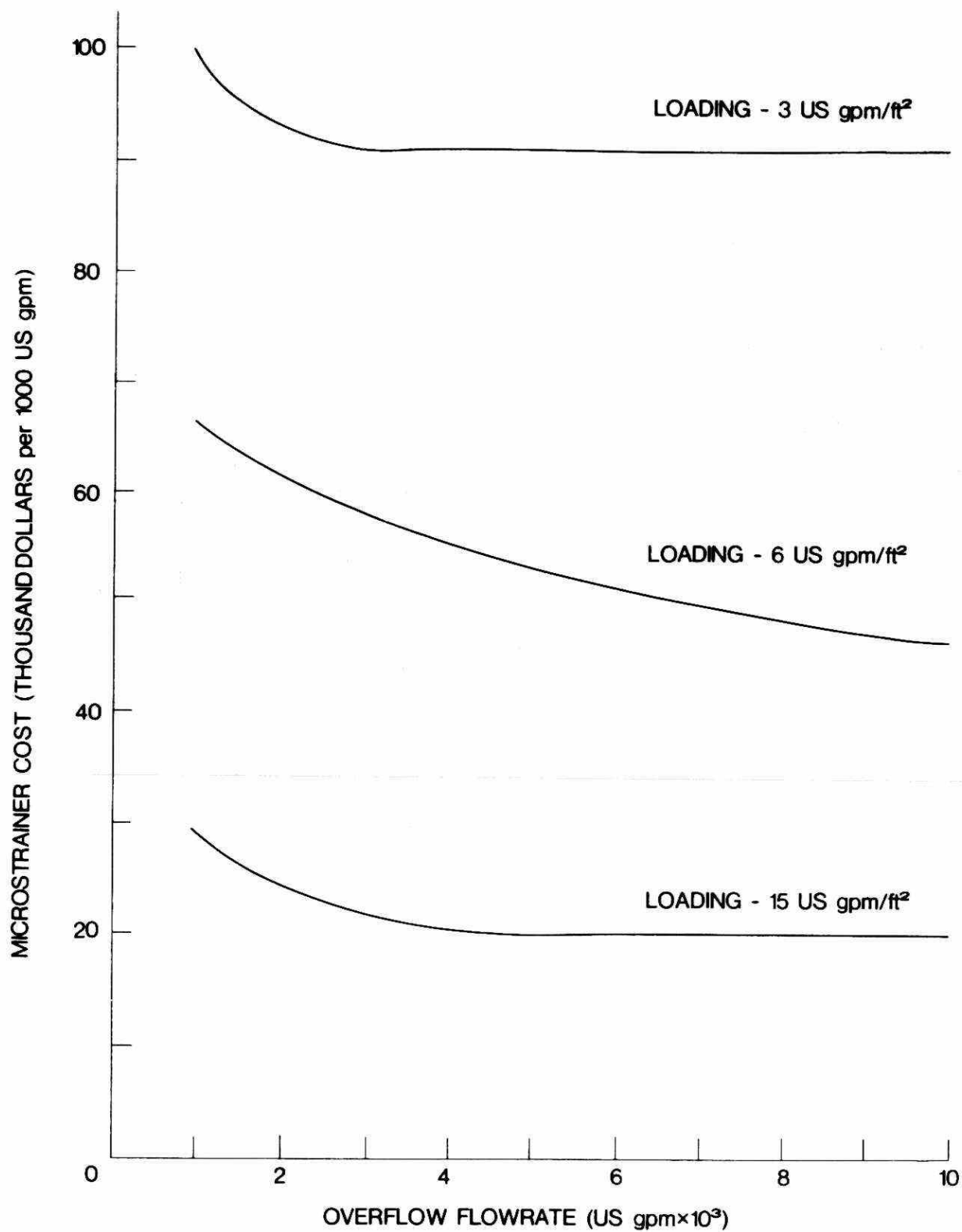


Figure 11 Microstrainer Cost as a Function of Overflow Flowrate and Loading

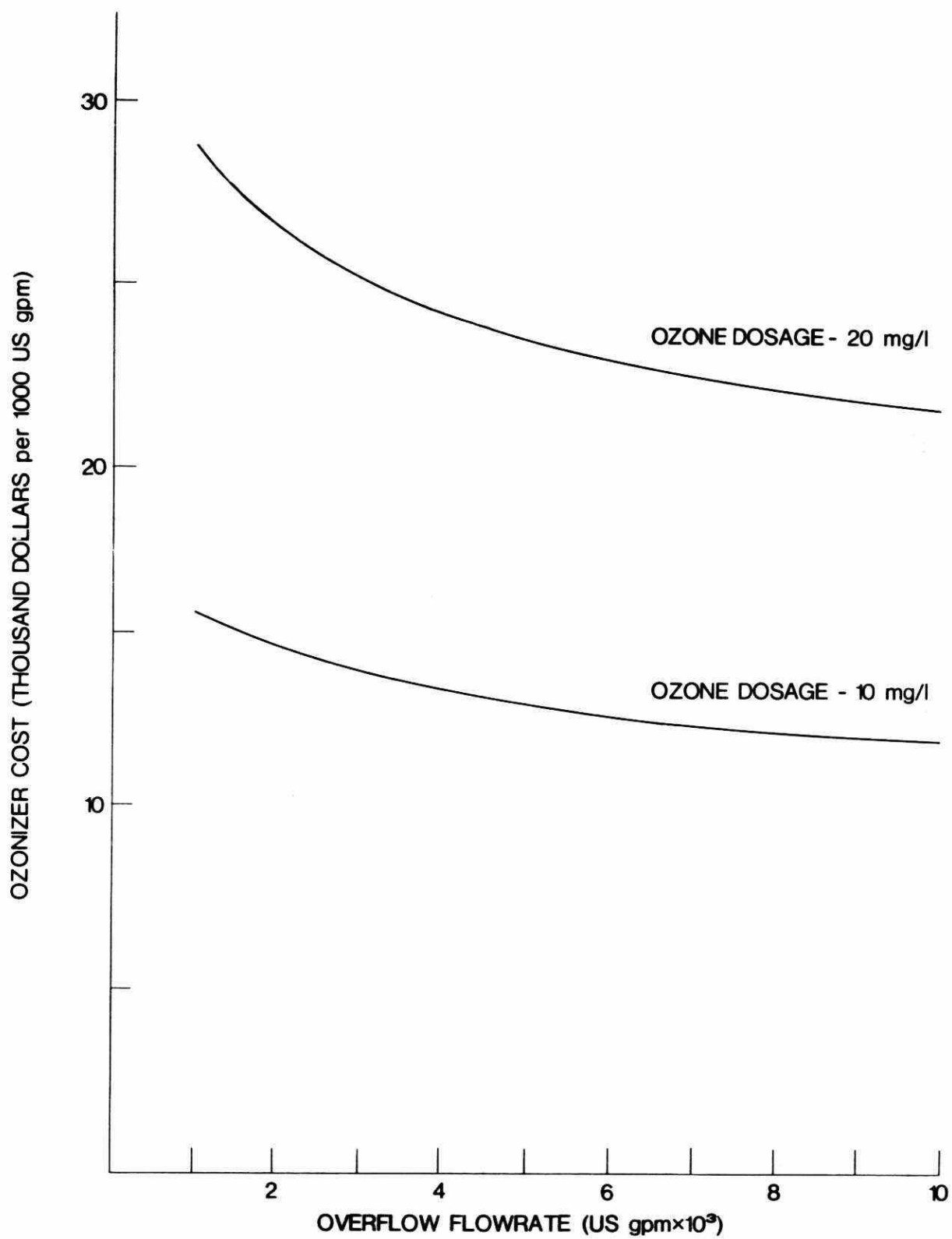


Figure 12 Ozonizer Cost as a Function of Overflow Flowrate and Ozone Dosage

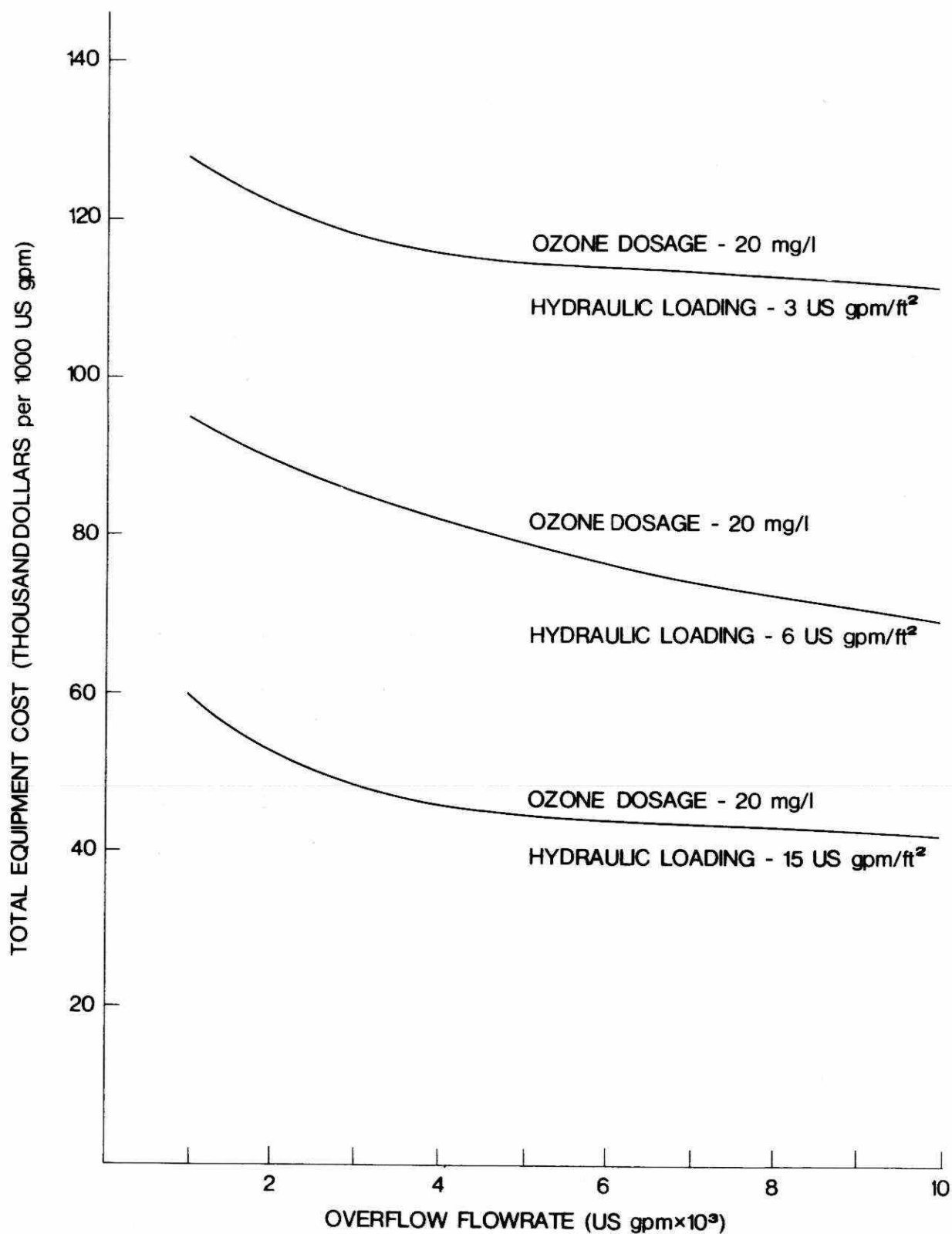


Figure 13 Total Equipment Cost as a Function of Overflow Flowrate, Hydraulic Loading and Ozone Dosage

From the figures, it is evident that the capital cost of the installation is highly dependent upon the screen throughput rate. The manufacturer of the Microstrainer claims to have successfully operated the unit on combined sewer overflows using throughput rates as high as 45 US gpm/ft². These observations were made on a much larger unit than the one used in this study. If it is possible to achieve such high throughput rates and still maintain satisfactory contaminant removal efficiencies, the capital cost of a prototype installation can be substantially reduced.

Operating costs for electrical power consumption (using \$0.01 per kwh) are estimated to be approximately \$1.10 per operating hour for each 1000 US gpm of design capacity. At least 95 percent of this cost would be associated with the ozonation equipment.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

From the results of the pilot scale evaluation of a Micro-strainer-ozonation system for the treatment of combined sewer overflows, the following conclusions can be drawn:

1. The Microstrainer is capable of removing a significant portion of the waste contaminants under optimum operating conditions.
2. An increase in the sewage suspended solids concentration resulted in a decline in the Microstrainer performance.
3. An increase in the hydraulic loading beyond the design rating of 3 US gpm/ft² adversely affected the performance of the unit.
4. The addition of ferric chloride and/or polyelectrolyte to the influent to the Microstrainer did not improve the treatment efficiency. This could be a result of inadequate mixing conditions or inherent deficiencies in the system for the removal of chemical floc.
5. Batch ozonation of the screened effluent resulted in greater than 99.9% reduction in the total coliform organisms concentration as well as a high degree of BOD removal.
6. Continuous ozonation of the screen effluent resulted in a significant reduction in the waste COD concentration. The removal efficiency increased at higher ozone dosages and longer contact times, attaining a maximum of 46 percent removal at a dosage of 20 mg/l ozone and 15 minutes contact time.
7. Continuous ozonation of a screened effluent sample spiked with lead nitrate indicated that this treatment is capable of reducing lead discharges resulting from snow-melt runoff. A maximum lead removal of 35 percent was attained at an ozone dosage of 20 mg/l and 15 minutes contact time.

8. Preliminary cost estimates indicate that the equipment costs for Microscreening at a throughput of 3 US gpm/ft² and ozonation at a dosage of 20 mg/l will be \$128,000 per 1000 US gpm at a design capacity of 1000 US gpm. Increasing the system capacity to 10,000 US gpm results in a decrease in capital expenditure to about \$113,000 per 1000 US gpm. Operating costs of the treatment system will be approximately \$1.10 per operating hour at 1000 US gpm.
9. The Microstrainer-ozonation treatment system is well-suited for the treatment of combined sewer overflows.

8.2 Recommendations

Based on the findings of the investigation using simulated combined sewer overflows, the following recommendations for further investigation are made:

1. The pilot scale microscreen-ozone treatment system should be operated on actual combined sewer overflows during a representative number of runoffs in order to evaluate the performance of the Microstrainer under actual conditions and verify the results obtained during the study using diluted raw sewage.
2. The continuous co-current ozone contact system should be used during these investigations in order to evaluate the ozone performance under realistic process conditions.
3. Subsequent to the evaluation of the pilot plant performance under actual operating conditions, further detailed investigations should be instigated in order to optimize the treatment efficiency in terms of hydraulic loading, differential liquid level, drum speed, ozone dosage, ozone contact time, and chemical additives.

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PART II

1. INTRODUCTION

Pollutech Pollution Advisory Services Limited was retained under the provisions of the Canada-U.S. Agreement on Great Lakes Water Quality, to investigate the applicability and feasibility of an advanced physical-chemical treatment system consisting of fine screening and ozonation for the high-rate treatment of waste resulting from the overflow of combined sewage collection systems. During the winter of 1974, the investigation was carried out at the West Oakville Water Pollution Control Plant using diluted raw sewage to simulate combined sewer overflow. The results of the investigation were detailed in PART I of this report.

Based on the favourable results of this investigation, it was decided to continue the study using actual combined sewer overflow as a feed to the pilot-scale treatment system. The following summarizes the results of the on-site investigation.

2. OBJECTIVES

The objectives of the on-site investigation of the pilot scale system treating actual combined sewer overflows were as follows:

- to install and debug the pilot-scale treatment system at a typical combined sewer overflow. The system consisted of a Microstrainer* in conjunction with a continuous co-current ozone contact column.
- to evaluate the effectiveness of the Microstrainer-ozone system for removing contaminants from actual combined sewer overflows.
- to compare the quality of actual combined sewer overflows to the diluted raw sewage used as synthetic feed during the investigation at the West Oakville Water Pollution Control Plant in order to relate the performance of the treatment system under actual and simulated conditions.

* Registered trademark, Crane Canada Ltd.

3. DESCRIPTION OF THE TEST SITE

After discussions with personnel from the Regional Municipality of Hamilton-Wentworth, Department of Engineering, and the Scientific Authority, and an examination of various combined sewer outfalls in the City of Hamilton, an overflow at Stroud Road and Delbrook Crescent in Hamilton was selected as typical of the outfalls in the local area. This outfall overflows into an open channel, flowing into Cootes Paradise and eventually into Hamilton Bay. The stormwater drainage system serves an area of approximately 1468 acres. The land use is principally residential with paved roads; also included is a large municipal golf course and a major hospital complex. Some light industries, primarily service-oriented, such as restaurants and car-washes, are served by the sewer system. During the test period, there was some housing construction in the immediate area of the outfall.

Dry weather flow in the sewer averages approximately 0.7 cfs, which flows to the Hamilton Water Pollution Control Plant. Under storm conditions, the test site serves as a treatment plant by-pass equipped with a gate which can be either automatically or manually closed to divert all the flow entering the outfall to the open channel. Thus, the initial surge of high strength waste resulting from the flushing of the streets and sewers will normally be passed to the treatment plant until the stormwater flow reaches a sufficient magnitude to require by-passing of the waste. Overflow only occurs when the gate leading to the treatment plant is closed. Therefore, the magnitude of the overflow flow-rate can change abruptly as the by-pass gate is opened or closed.

4. EXPERIMENTAL PROCEDURES

The on-site Microstrainer installation was virtually unchanged from that employed during the study at the West Oakville Water Pollution Control Plant and was described in detail in Part I of this report. For this investigation, the continuous co-current ozone contact chamber was used to evaluate the effectiveness of ozone for the disinfection and polishing of the screened waste. The apparatus used was identical to that employed in the initial study for optimization of the ozone dosage and contact time, and was also described in detail in Part I. A schematic of the pilot scale treatment system is included as Figure 1.

Three overflows were monitored during this investigation. During the first run, the raw waste was fed to the Microstrainer at the design hydraulic loading (3.0 US gpm/ft^2) for the entire run and the volumetric flowrate of the overflow estimated by measurement of the head above the overflow wall. During the two subsequent runs, the feed flowrate to the Microstrainer was varied proportionally with the flowrate of the combined sewer overflow. The proportionality between the overflow flowrate and Microstrainer feed rate was changed between the second and third runs, dependent on the intensity of the rainfall and magnitude of the overflow, in order to maintain the hydraulic loading of the screen at less than 6 US gpm/ft^2 . Grab samples of the raw feed, screened effluent and ozonated final effluent were taken at intervals of 15 or 30 minutes in order to evaluate the contaminant concentration profiles across the treatment system.

Due to the limited capacity of the ozone generator (up to 10 gm of ozone per hour), the entire flow through the pilot plant could not be treated in the ozone contact column. Therefore, a portion of the effluent flow from the Microstrainer was treated such that a constant dosage of 20 mg/l ozone and a constant contact time of 15 minutes was maintained.

The efficiency of the pilot plant was evaluated in terms of the total BOD, total organic carbon, suspended solids, total phosphorus, total coliform count, oil and grease and true colour concentration profiles. The soluble lead content of the waste was always less than

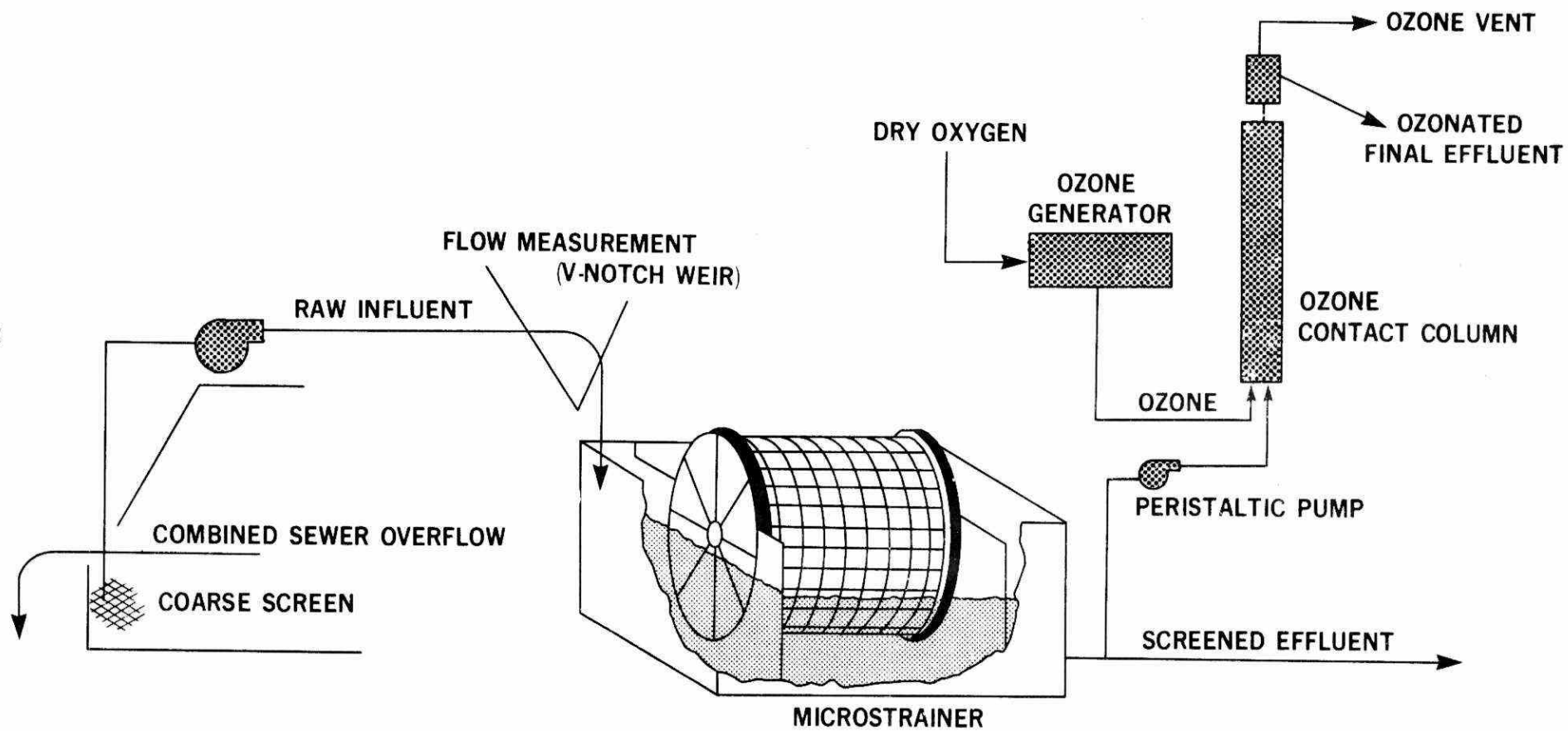


Figure 1. Schematic Representation of Pilot Plant Installation

0.25 mg/l and the concentration profile and removal efficiency in terms of lead could not be evaluated at these low levels.

5. RESULTS

The average removal efficiency of the pilot-scale Microstrainer - ozonation system obtained under simulated and actual feed conditions are compared in Table 1. The removal obtained during the simulation runs at the West Oakville Water Pollution Control Plant was based on analysis of composite samples. The removal efficiency attained during the "on-site" runs was based on grab sampling and, whenever the results indicated an increase in the concentration of a parameter across the pilot plant, the percent removal was considered to be zero for the purposes of averaging the data. The results indicate an absolute decrease of between 6 and 38 percent in the removal efficiency of the various parameters under actual operating conditions as compared to the simulation runs. The reduction in removal efficiency in terms of total coliform organisms and, to some extent the other parameters, was probably due to the different ozonation techniques used during the two studies. The screened effluent in the simulated runs conducted at the Oakville treatment plant was treated batchwise with extremely high dosages of ozone (nominal dosage - 1675 mg/l ozone), whereas the screened effluent in the actual combined sewer overflow tests was treated in a continuous contact column with a dosage of only 20 mg/l ozone. The mixing conditions in the ozone contact column were not investigated in this study and it is possible that improved mixing patterns may result in better removal efficiencies.

The average influent strength of the pilot plant feed for both studies is compared in Table 2. The simulated feed which resulted from diluting the raw domestic sewage at the Oakville Water Pollution Control Plant was more concentrated than the actual combined sewer overflow sampled at the test site, except in terms of suspended solids content. The actual combined sewage contained a high concentration of very fine clay particles, probably resulting from runoff from the local construction sites. This material was not removed significantly by the "on-site" treatment system.

TABLE 1. COMPARISON OF PILOT PLANT PERFORMANCE USING
SIMULATED AND ACTUAL COMBINED SEWER OVERFLOW

PARAMETER	OVERALL PERCENT REMOVAL	
	Simulated Combined Sewer Overflow	Actual Combined Sewer Overflow
Total BOD	67	29.2
Total Organic Carbon	28	11.2
Suspended Solids	40	29.6
Total Phosphorus	26	19.6
Oil and Grease	50	39.4
True Colour	64	35.0
Total Coliform	99.9	76.0

TABLE 2. COMPARISON OF SIMULATED AND ACTUAL COMBINED
SEWER OVERFLOW CHARACTERISTICS

PARAMETER	AVERAGE INFLUENT CONCENTRATION	
	Simulated Combined Sewer Overflow	Actual Combined Sewer Overflow
Total BOD (mg/l)	122	28
Total Organic Carbon (mg/l)	70	26
Suspended Solids (mg/l)	82	214
Total Phosphorus (mg/l)	3.37	0.76
Oil and Grease (mg/l)	7.6	2.3
True Colour (Co-Pt standard)	61	38
Total Coliform (cells per 100 ml)	4,150,000	1,560,000

The concentration profiles in terms of the more significant parameters; BOD, suspended solids and total coliform counts, for all experimental conditions are illustrated in the form of probability plots in Figures 2, 3 and 4, respectively. (This method of data presentation is not an attempt to indicate the degree of contaminant removal which might be expected from each stage of the treatment system. Rather, it facilitates visualization of the results as ambiguities and random variations in the data are not reflected when the results are presented in this manner.)

During the investigation using diluted raw sewage at the Oakville Water Pollution Control Plant, it was found that increased hydraulic loadings beyond the design rating of 3 US gpm/ft² and/or increased suspended solids concentrations in the feed resulted in a decline in the performance of the Microstrainer. This result could not be confirmed during the on-site investigation, probably because of the rapidly changing overflow characteristics and the use of grab samples to characterize the treatment system performance.

5.1 Results of Run 1 - June 18, 1974

The concentration profiles in terms of BOD and suspended solids are given in Table 3 and the remaining parameters are summarized in Table 4. The operational conditions during the run are summarized in Table 5. The rainfall during the experimental period was not extremely intense and was not predicted to last overly long; therefore, only the raw influent and ozonated final effluent were sampled. After one hour of run-time the diversion gate opened, sending the entire sewer flow to the Hamilton treatment plant and the pilot plant had to be shut down. Total precipitation for June 18, 1974, was 0.49 inches as recorded at the Hamilton Civic Airport, but the majority of the rainfall occurred during the late evening and night when the pilot plant was not operational.

During this run, the microscreen hydraulic loading was maintained at the design level of 3 US gpm/ft² and Table 5 indicates that the differential head across the screen was within the optimum range of 3 to 5 inches throughout the run.

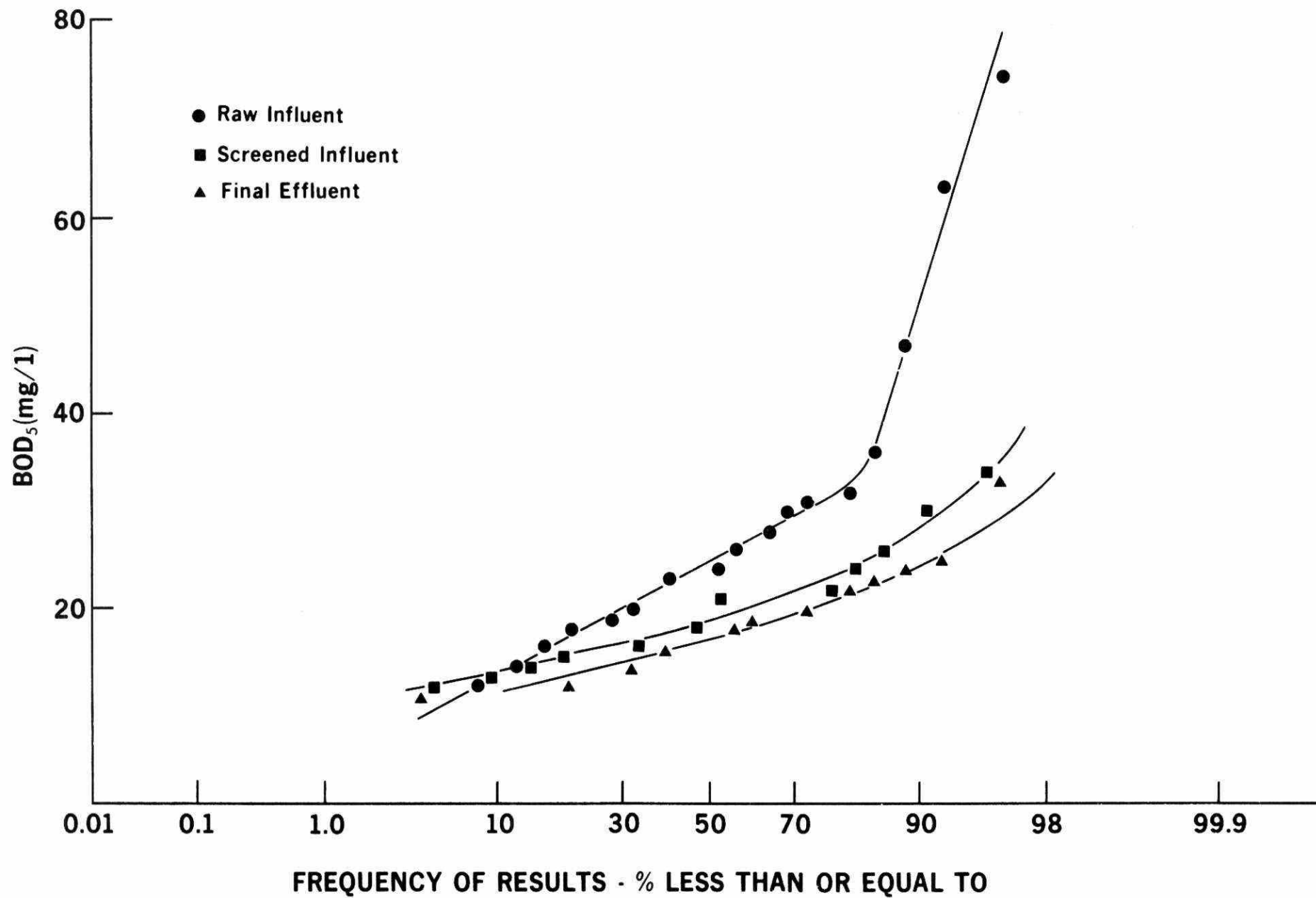


Figure 2 BOD₅ Concentration Profile Across Pilot Plant

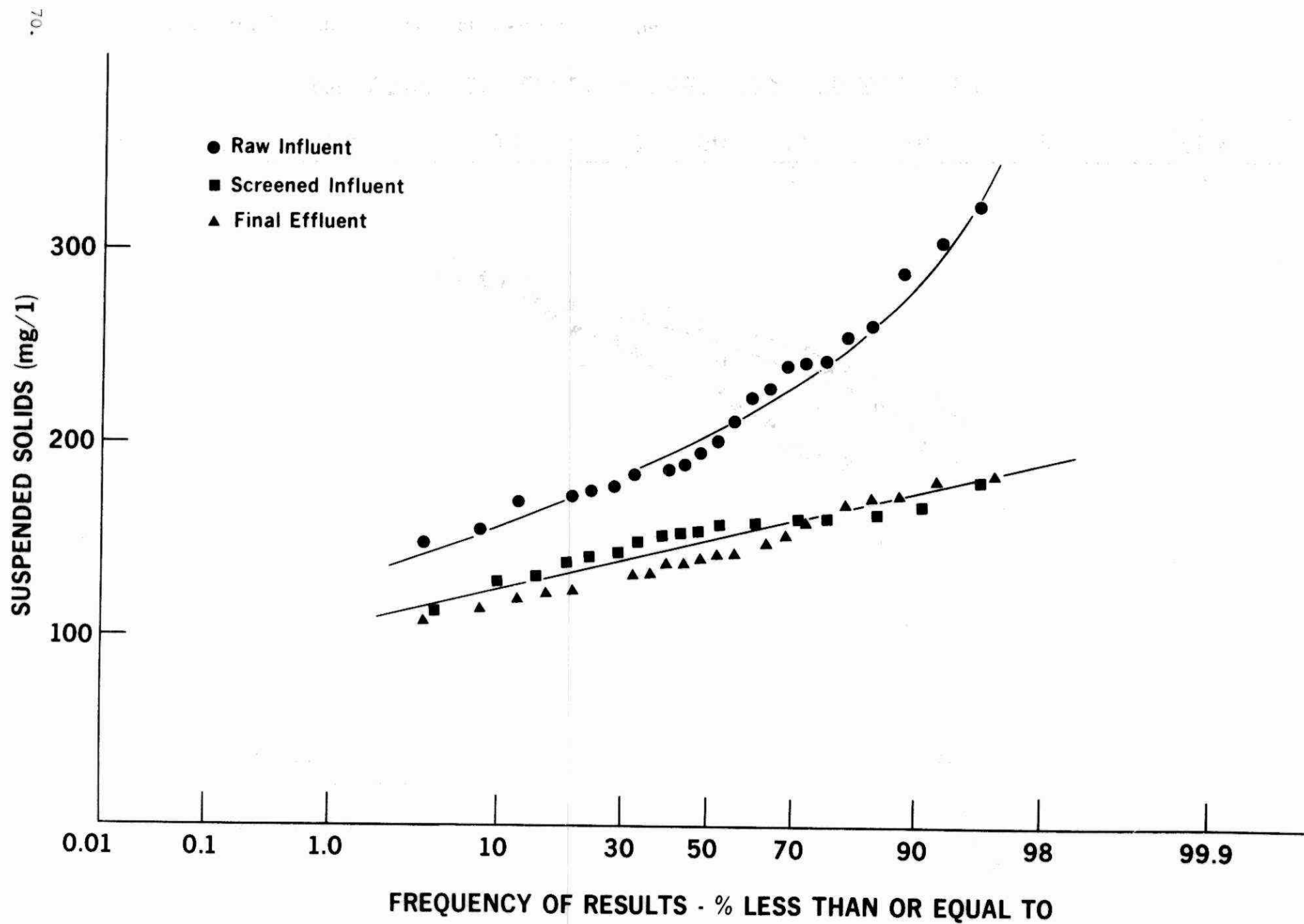


Figure 3 Suspended Solids Concentration Profile Across Pilot Plant

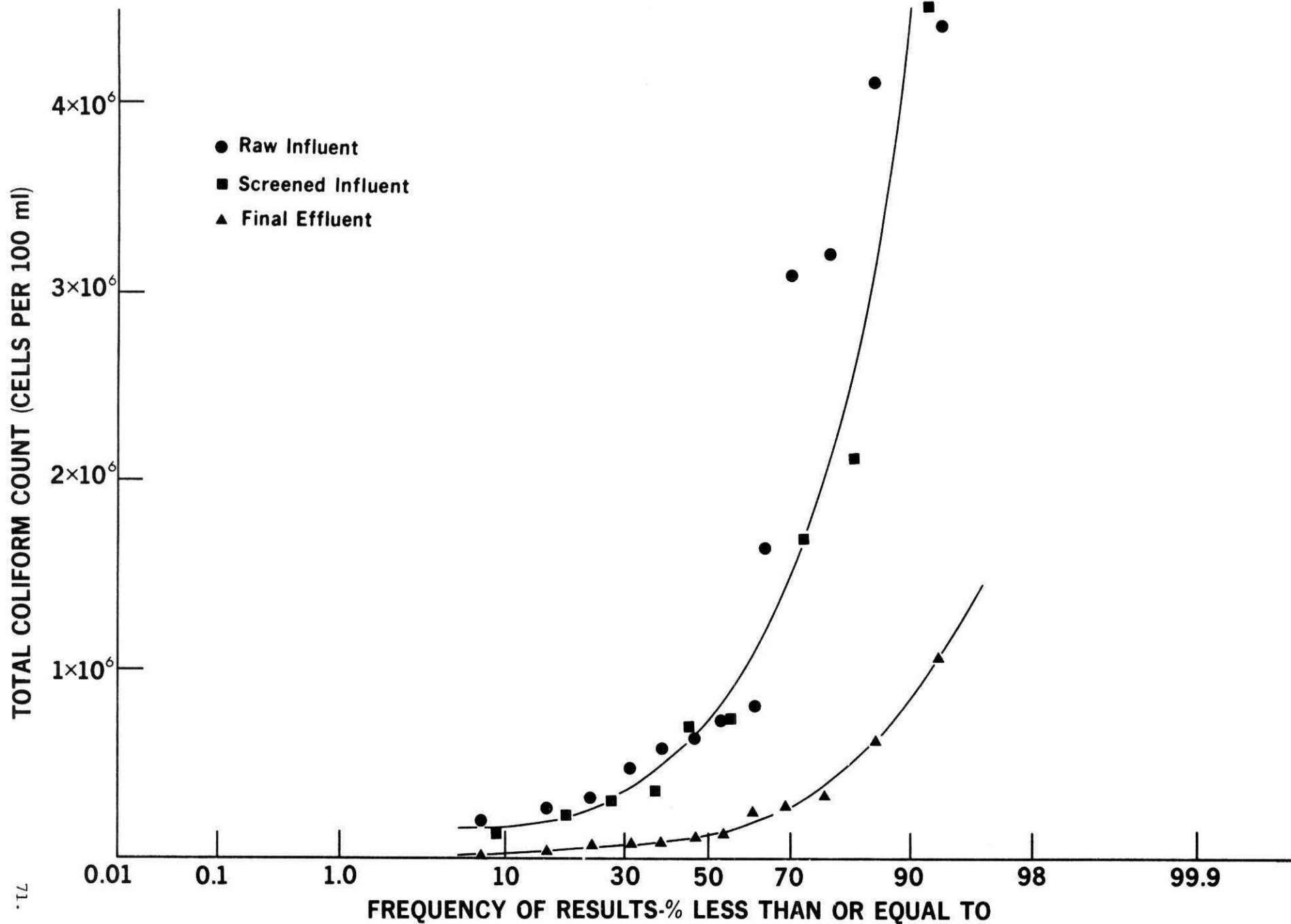


Figure 4 Total Coliform Count Profile Across Pilot Plant

TABLE 3. PILOT PLANT PERFORMANCE - BOD AND SUSPENDED SOLIDS CONCENTRATION PROFILES

Run 1 - June 18, 1974						
Sampling Time	Suspended Solids (mg/l)			BOD (mg/l)		
	Raw Influent	Final Effluent	Percent Removal	Raw Influent	Final Effluent	Percent Removal
13:15	172	144	16.3	28	25	1.1
13:30	184	182	1.1	63	23	63.5
13:45	262	184	29.8	47	24	48.9
14:00	212	138	34.9	74	33	55.4
AVERAGE OVERALL PERCENT REMOVAL	--	--	20.5	--	--	42.3

TABLE 4. PILOT PLANT PERFORMANCE - MISCELLANEOUS CONCENTRATION PROFILES

(Run 1 - June 18, 1974)

Sampling Time	Sample Description	Concentration of Parameter					
		Total Phosphorus (mg/l)	Total Organic Carbon (mg/l)	Oil and Grease (mg/l)	Total Coliform (cells per 100ml)	True Colour (Co-Pt)	Soluble Lead (mg/l)
13:15	Raw Influent	0.70	28	0.7	300,000	40	<0.25
	Final Effluent	0.49	25	0.2	261,000	20	--
13:45	Raw Influent	1.70	33	1.0	252,000	40	<0.25
	Final Effluent	0.79	29	1.4	87,000	20	--

TABLE 5. PILOT PLANT OPERATIONAL PARAMETERS

Run 1 - June 18, 1974

Time	Overflow Flowrate (cfs)	Microstrainer Loading ₂ (US gpm/ft ²)	Differential Head (inches)	Backwash Flowrate (US gpm)	Backwash Pressure (psig)	Ozonation Contact Time (min.)	Ozone Dosage (mg/l)
13:00	11.0	3.0	5	2.4	20	15	20
13:15	8.8	3.0	5	2.0	20	15	20
13:30	8.8	3.0	4-1/2	1.9	25	15	20
13:45	6.6	3.0	4-1/2	1.8	25	15	20
14:00	7.9	3.0	5	1.8	25	15	20

5.2 Results of Run #2 - June 19, 1974 (A.M.)

The concentration profiles across the pilot scale treatment system in terms of BOD and suspended solids for the second overflow monitored are summarized in Table 6 and the profiles with respect to the remaining parameters are given in Table 7. These results are also plotted in Figures 5 to 9 for total BOD, suspended solids, total coliform count, oil and grease and colour. The remaining contaminants, total organic carbon and total phosphorus, do not warrant graphical presentation due to their extremely low removal across the treatment system.

The operational conditions during this run are summarized in Table 8. As indicated, the hydraulic loading of the Microstrainer was varied, dependent on the overflow rate, up to a maximum of 6.0 US gpm/ft², twice the design loading. At loadings of up to 5.0 US gpm/ft², the differential head across the Microstrainer could be maintained within the manufacturer's recommended limits of 3 to 5 inches. However, at the maximum hydraulic loading, the differential liquid level increased to between 6 and 7 inches.

The runoff during the morning of June 19, 1974, was much greater than experienced during the first run as indicated by the overflow flowrate data. Total rainfall on June 19, 1974, as recorded at Hamilton Civic Airport was 0.44 inches, most of which occurred during the late morning and early afternoon. However, the overflow ceased abruptly after about 3 hours of run time and the second run was terminated.

5.3 Results of Run 3 - June 19, 1974 (P.M.)

During the early afternoon of June 19, 1974, a significantly heavier rainfall occurred which resulted in a second overflow at the test site. This overflow was monitored for a period of about three hours and the profiles in terms of BOD and suspended solids concentrations across the treatment system are summarized in Table 9. The data in terms of the remaining parameters are given in Table 10 and all concentration profiles are illustrated graphically in Figures 10 to 14 for BOD, suspended solids, total coliform count, oil and grease, and colour, respectively.

TABLE 6.

PILOT PLANT PERFORMANCE - BOD AND SUSPENDED SOLIDS CONCENTRATION PROFILES

(Run 2 - June 19, 1974 [A.M.])

Sampling Time	Suspended Solids (mg/l)					BOD (mg/l)				
	Raw Influent	Screened Influent	Microstrainer Removal %	Final Effluent	Overall Removal %	Raw Influent	Screened Influent	Microstrainer Removal %	Final Effluent	Overall Removal %
9:30	195	111	43.1	122	37.4	24	22	8.3	18	25.0
9:45	201	127	36.8	112	44.3	32	30	6.3	20	37.5
10:00	324	148	54.3	106	67.3	36	26	27.8	16	55.5
10:15	244	154	36.9	141	42.2	23	22	4.3	18	21.7
10:30	189	167	11.6	139	26.5	24	24	--	20	16.7
10:45	256	161	37.1	168	34.4	23	22	4.3	18	21.7
11:00	187	157	16.0	148	20.9	30	34	--	22	26.7
11:15	169	164	3.0	118	30.2	19	21	--	22	--
11:30	289	153	47.1	160	44.6	29	22	24.1	12	58.6
11:45	187	159	15.0	154	17.6	26	22	15.4	20	23.1
AVERAGE PERCENT REMOVAL	--	--	30.1	--	36.5	--	--	9.1	--	28.7

TABLE 7. PILOT PLANT PERFORMANCE - MISCELLANEOUS CONCENTRATION PROFILES

(Run 2 - June 19, 1974 [A.M.])

Sampling Time	Sample Description	Concentration of Parameter					
		Total Phosphorus (mg/l)	Total Organic Carbon (mg/l)	Oil and Grease (mg/l)	Total Coliform (cells per 100ml)	True Colour (Co-Pt)	Soluble Lead (mg/l)
9:30	Raw Influent	0.88	28	4.5	800,000	20	<0.25
	Screened Influent	0.70	27	2.2	350,000	20	--
	Final Effluent	0.65	25	1.6	110,000	20	--
10:00	Raw Influent	1.18	37	5.8	640,000	20	<0.25
	Screened Influent	0.71	33	1.9	100,000	20	--
	Final Effluent	0.76	29	1.4	80,000	20	--
10:30	Raw Influent	0.90	24	2.4	470,000	20	<0.25
	Screened Influent	0.86	29	0.9	300,000	15	--
	Final Effluent	0.67	26	1.5	250,000	15	--
11:00	Raw Influent	0.74	33	2.0	560,000	30	<0.25
	Screened Influent	0.75	30	1.5	730,000	17	--
	Final Effluent	1.00	33	0.5	130,000	10	--
11:30	Raw Influent	0.58	34	1.9	730,000	30	<0.25
	Screened Influent	0.70	21	1.5	210,000	15	--
	Final Effluent	0.92	19	0.8	60,000	10	--

TABLE 8. PILOT PLANT OPERATIONAL PARAMETERS

(Run 2 - June 19, 1974 [A.M.])

Time	Overflow Flowrate (cfs)	Microstrainer Loading (US gpm/ft ²)	Differential Head (inches)	Backwash Flowrate (US gpm)	Backwash Pressure (psig)	Ozonation Contact Time (min)	Ozone Dosage (mg/l)
9:15	13.0	4.5	5	2.0	32	15	20
9:30	11.9	4.2	5-1/2	3.0	29	15	20
9:45	11.9	4.2	5-1/2	2.0	33	15	20
10:00	--	2.0	3	1.8	26	15	20
10:15	--	2.0	4	1.7	31	15	20
10:30	--	2.0	4	1.7	31	15	20
10:45	15.3	5.0	4-1/2	2.7	25	15	20
11:00	20.6	6.0	6	2.2	30	15	20
11:15	20.6	6.0	7	2.5	30	15	20
11:30	18.7	6.0	7	2.3	33	15	20
11:45	18.7	6.0	6-1/2	2.2	32	15	20

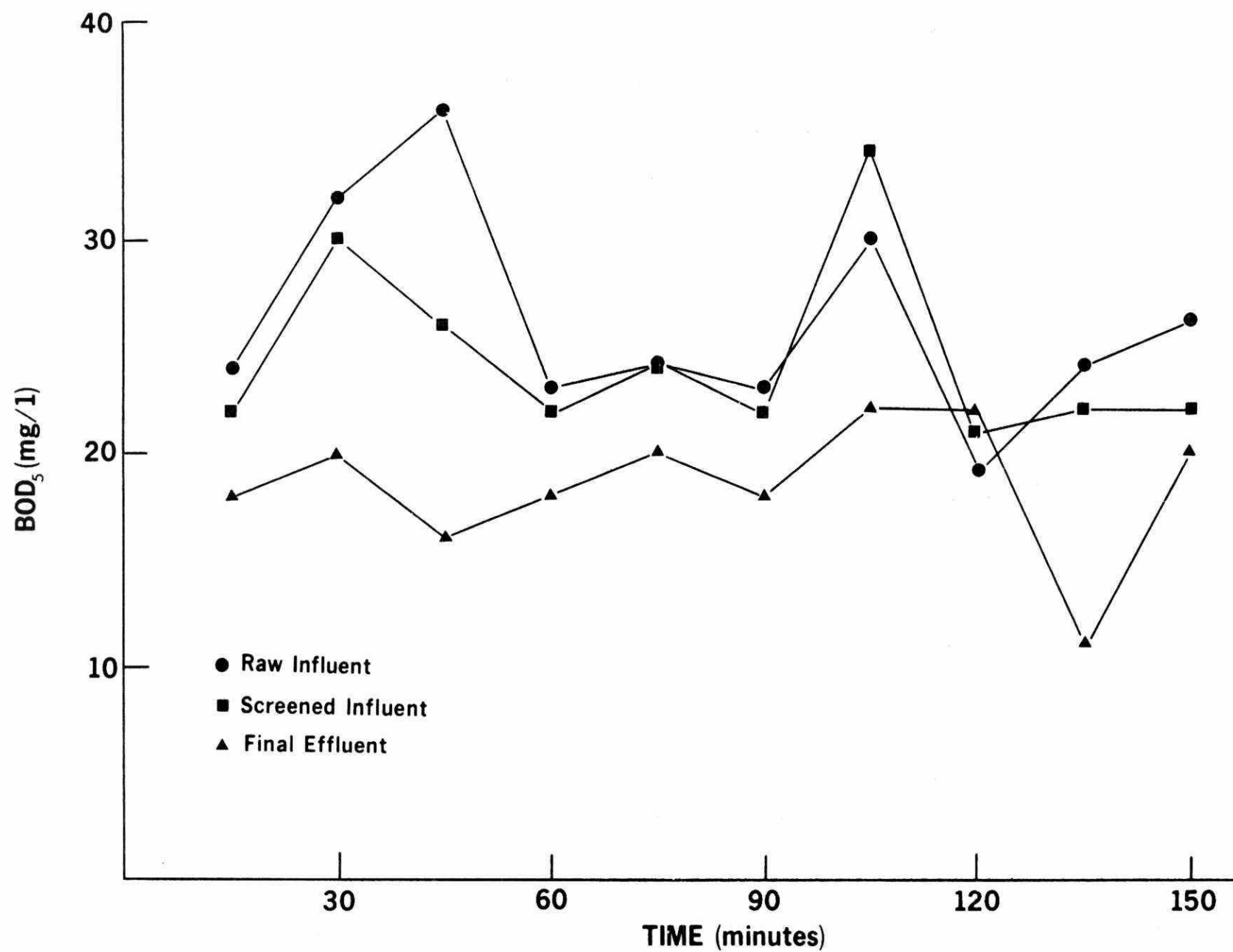


Figure 5 BOD Concentration Profile During Run 2 (June 19, 1974 A.M.)

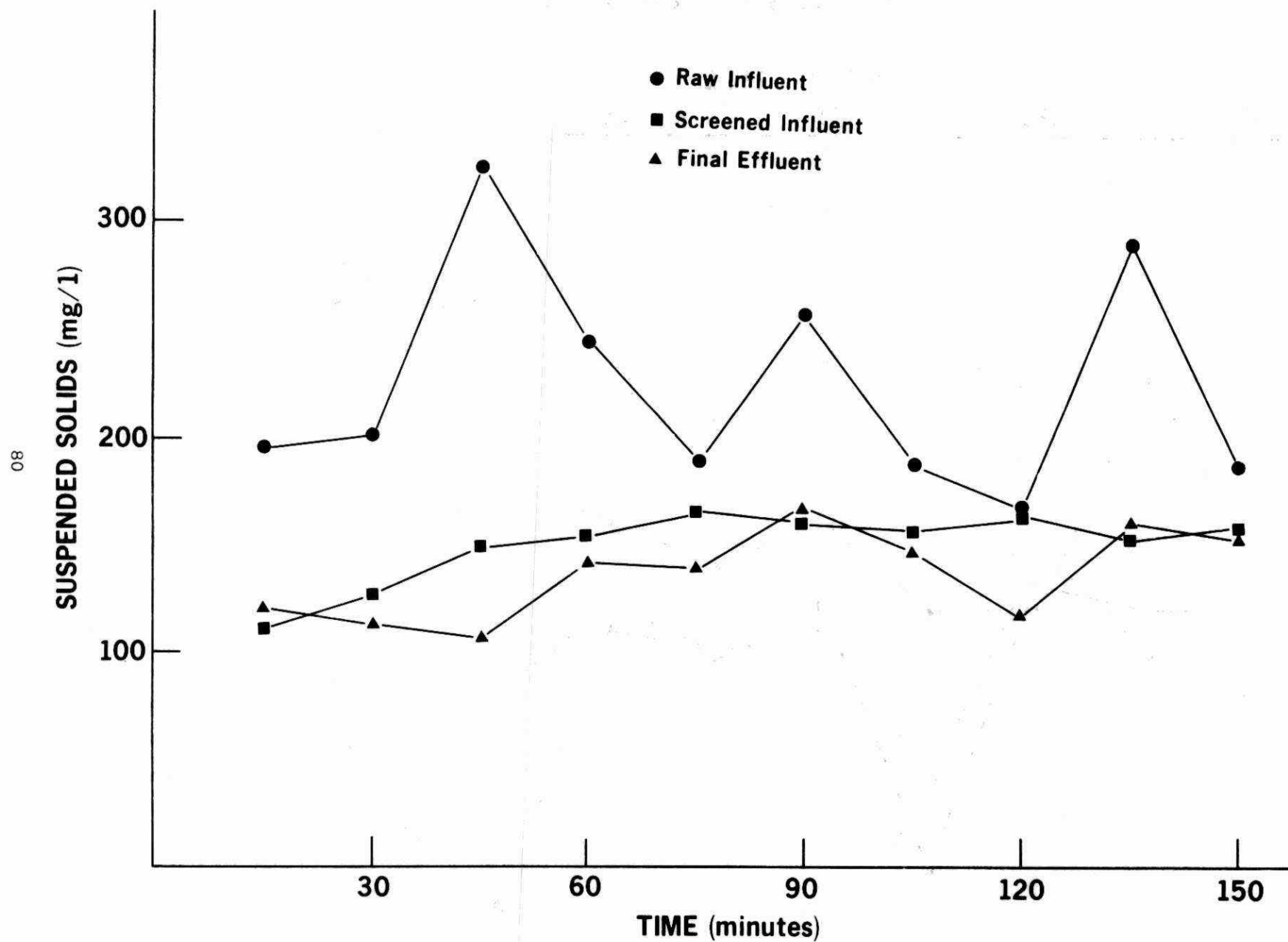


Figure 6 Suspended Solids Concentration Profile During Run 2 (June 19, 1975 A.M.)

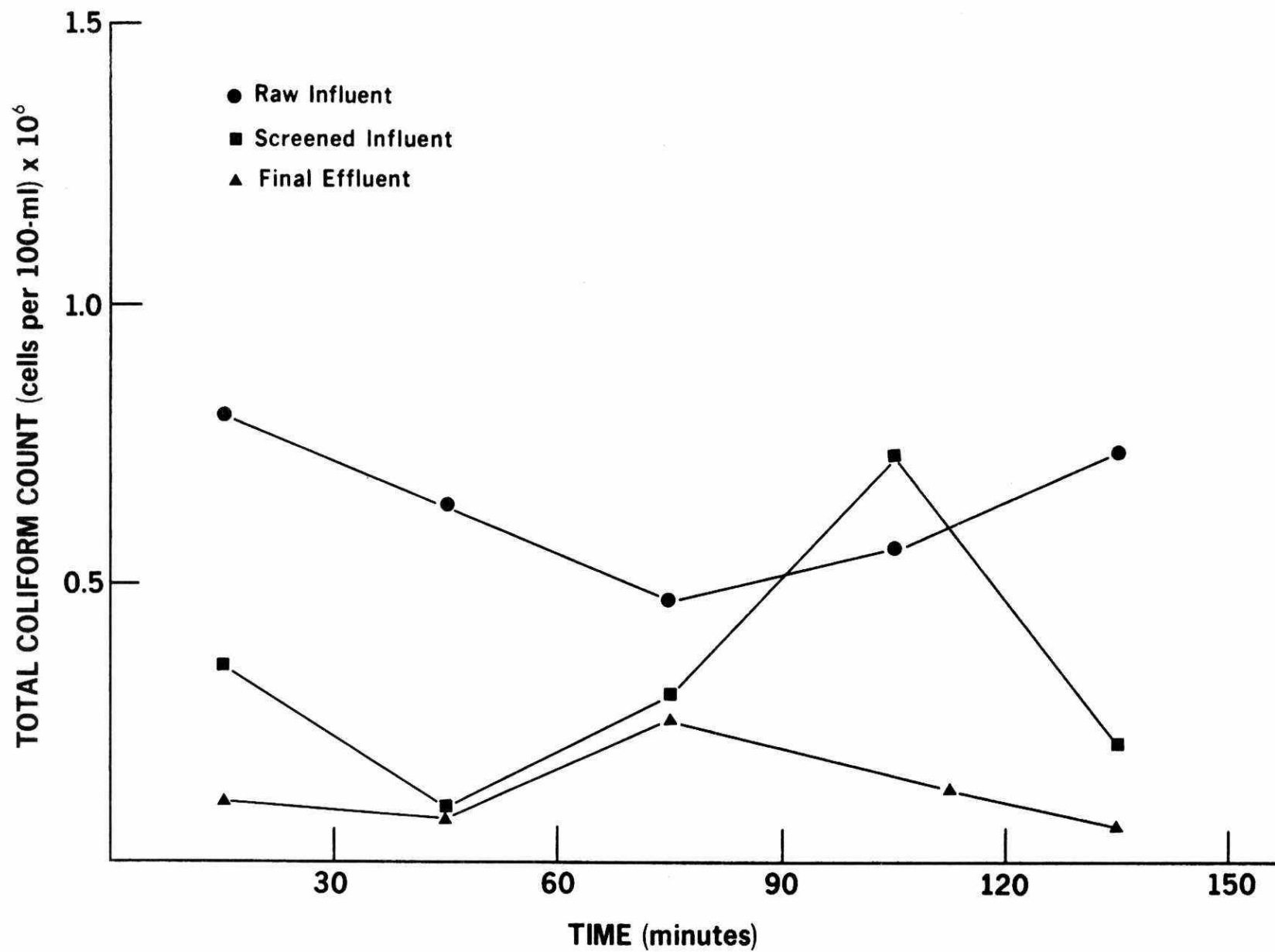


Figure 7 Total Coliform Count Profile During Run 2 (June 19, 1974 A.M.)

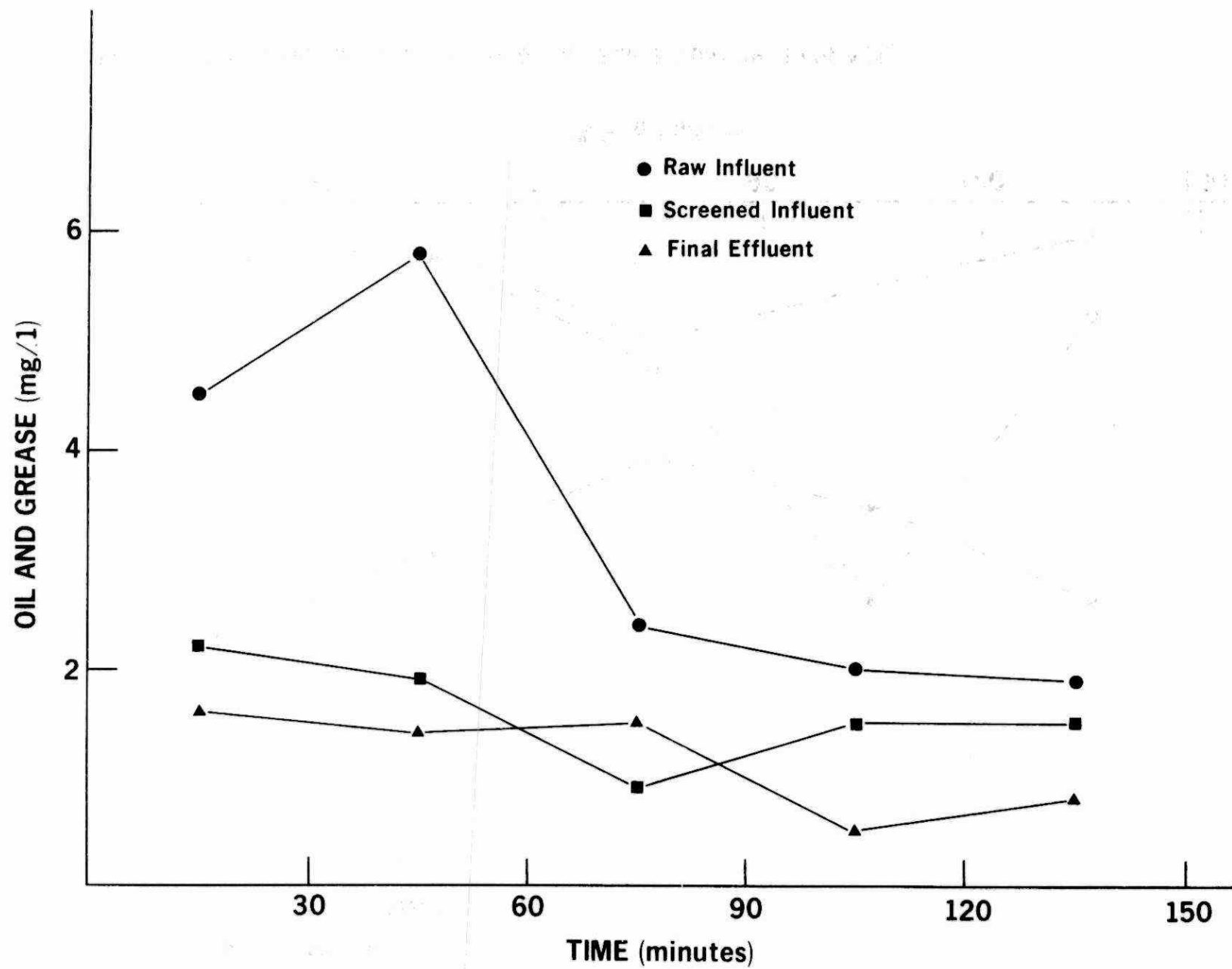


Figure 8 Oil And Grease Concentration Profile During Run2 (June 19, 1974 A.M.)

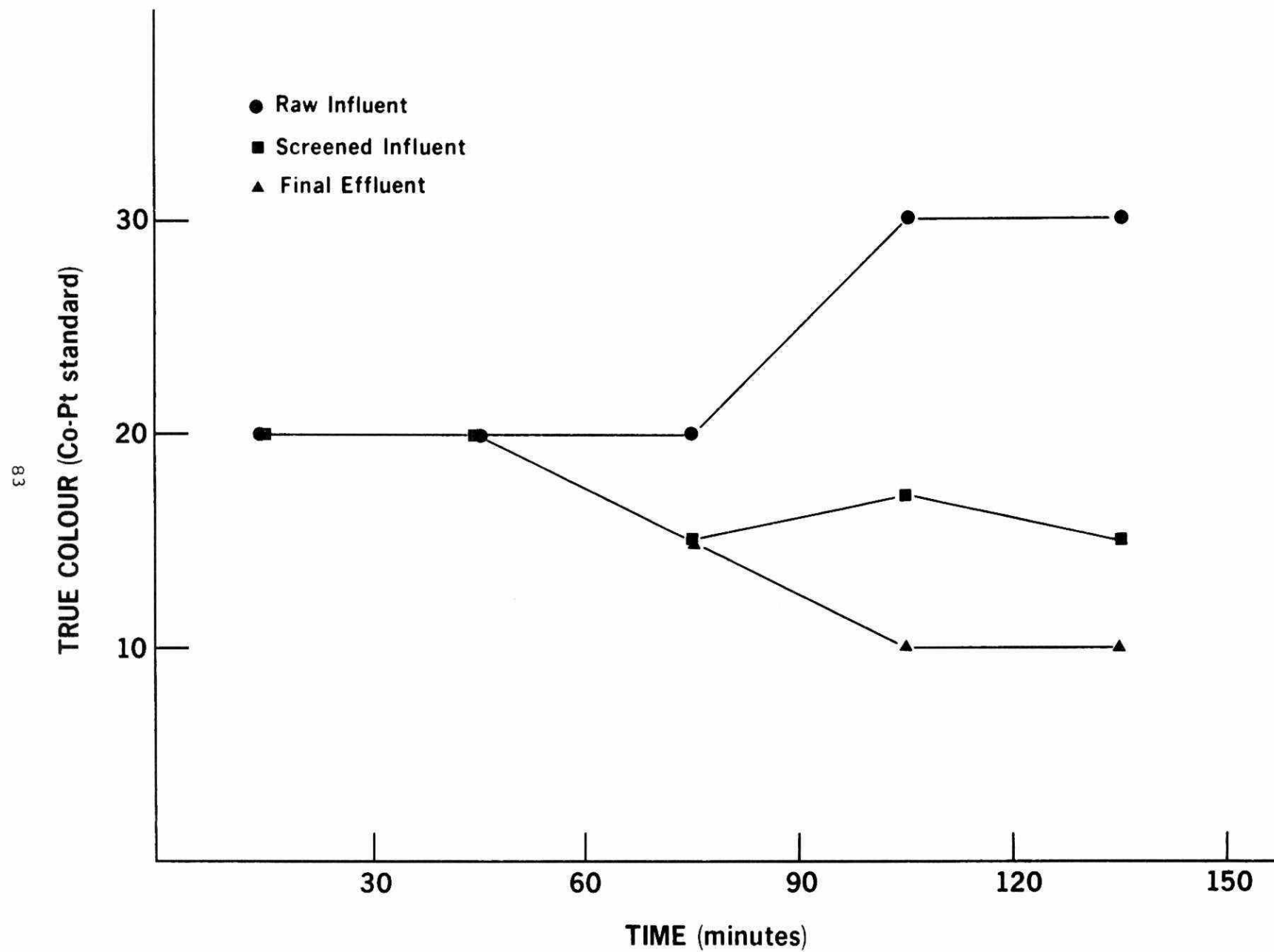


Figure 9 True Colour Concentration Profile During Run 2 (June 19, 1974 A.M.)

The operating conditions for the third run are summarized in Table 11. The overflow flowrate was relatively constant during this run, but the proportionality between the overflow flowrate and screen hydraulic loading was changed from that used during the second run due to the excessive differential head observed at the highest hydraulic loading in that test.

The differential liquid level across the Microstrainer was higher during this run than observed previously. An increase of solids in the Microstrainer drum was observed as the runs continued, but no fresh-water was available at the test site to flush the unit. Similar drainage problems were encountered as those experienced during the simulation runs at Oakville.

TABLE 9. PILOT PLANT PERFORMANCE - BOD AND SUSPENDED SOLIDS CONCENTRATION PROFILE

(Run 3 - June 19, 1974 [P.M.])

Sampling Time	Suspended Solids (mg/l)					BOD (mg/l)				
	Raw Influent	Screened Influent	Microstrainer Removal %	Final Effluent	Overall Removal %	Raw Influent	Screened Influent	Microstrainer Removal %	Final Effluent	Overall Removal %
13:45	154	152	1.3	144	6.5	20	18	10.0	16	20.0
14:00	174	159	8.6	160	8.0	31	18	41.9	12	61.3
14:15	147	143	2.7	128	12.9	28	16	42.9	19	32.1
14:30	177	140	20.9	143	19.2	19	18	5.3	18	5.3
14:45	172	164	4.7	133	22.7	18	15	16.7	11	38.9
15:00	240	137	42.9	132	45.0	12	12	--	14	--
15:15	228	181	20.6	179	21.5	14	13	7.1	14	--
15:30	223	161	27.8	132	40.8	16	16	--	12	25.0
15:45	242	130	46.3	171	29.3	32	16	50.0	12	62.5
16:00	304	163	46.4	132	56.6	12	14	--	14	--
AVERAGE PERCENT REMOVAL	--	--	22.2	--	26.3	--	--	17.3	--	24.5

TABLE 10. PILOT PLANT PERFORMANCE - MISCELLANEOUS CONCENTRATION PROFILES

(Run 3 - June 19, 1974 [P.M.])

Sampling Time	Sample Description	Concentration of Parameter					
		Total Phosphorus (mg/l)	Total Organic Carbon (mg/l)	Oil and Grease (mg/l)	Total Coliform (cells per 100ml)	True Colour (Co-Pt)	Soluble Lead (mg/l)
13:45	Raw Influent	0.90	30	2.5	190,000	55	0.25
	Screened Influent	0.82	28	1.8	690,000	59	--
	Final Effluent	0.45	24	1.7	7,000	35	--
14:15	Raw Influent	0.41	16	3.2	4,400,000	60	0.25
	Screened Influent	0.70	18	2.8	1,650,000	45	--
	Final Effluent	0.71	25	2.5	1,080,000	35	--
14:45	Raw Influent	0.37	15	1.3	3,100,000	40	0.25
	Screened Influent	0.56	17	1.1	4,800,000	40	--
	Final Effluent	0.64	13	0.9	30,000	30	--
15:15	Raw Influent	0.37	7	0.9	3,200,000	40	0.25
	Screened Influent	0.59	9	0.9	1,700,000	40	--
	Final Effluent	0.55	7	1.0	620,000	30	--
15:45	Raw Influent	0.47	23	1.0	4,100,000	60	0.25
	Screened Influent	0.39	22	1.1	2,120,000	55	--
	Final Effluent	0.41	23	1.0	310,000	40	--

TABLE 11. PILOT PLANT OPERATIONAL PARAMETERS

(Run 3 - June 19, 1974 [P.M.])

Time	Overflow Flowrate (cfs)	Microstrainer Loading (US gpm/ft ²)	Differential Head (inches)	Backwash Flowrate (US gpm)	Backwash Pressure (psig)	Ozonation Contact Time (min.)	Ozone Dosage (mg/l)
13:30	20.6	3.0	5	2.0	33	15	20
13:45	20.6	3.0	5	1.8	34	15	20
14:00	19.4	2.8	4-1/2	2.3	28	15	20
14:15	20.6	3.0	4-1/2	2.3	28	15	20
14:30	20.0	2.9	5	2.4	29	15	20
14:45	19.4	2.8	5	2.2	28	15	20
15:00	21.5	3.2	5	2.3	28	15	20
15:15	22.5	3.4	5-1/2	2.4	29	15	20
15:30	21.0	3.1	5	2.3	30	15	20
15:45	20.6	3.0	5	2.4	30	15	20
16:00	19.4	2.8	5	2.3	31	15	20

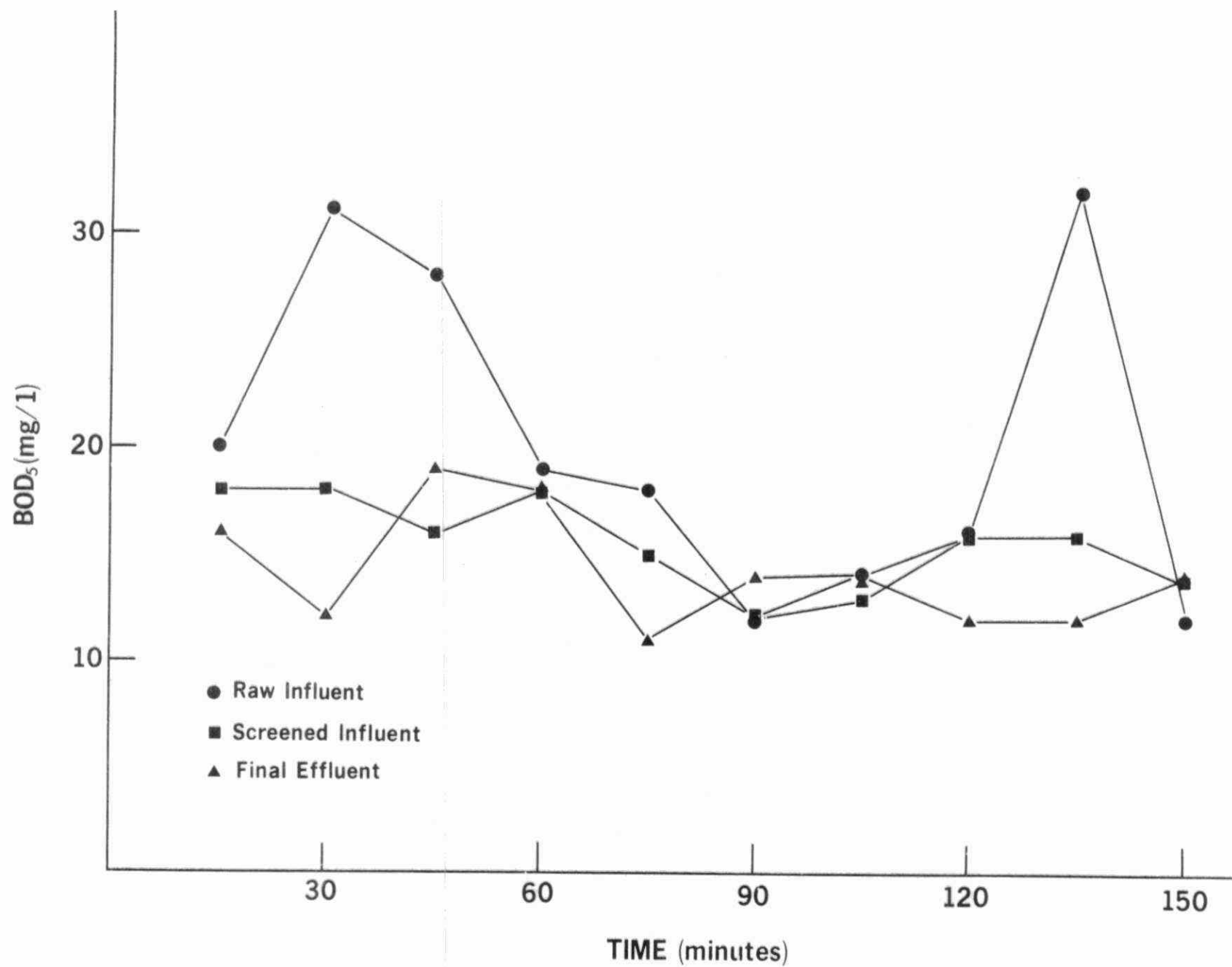


Figure 10 BOD Concentration Profile During Run 3 (June 19, 1974 P.M.)

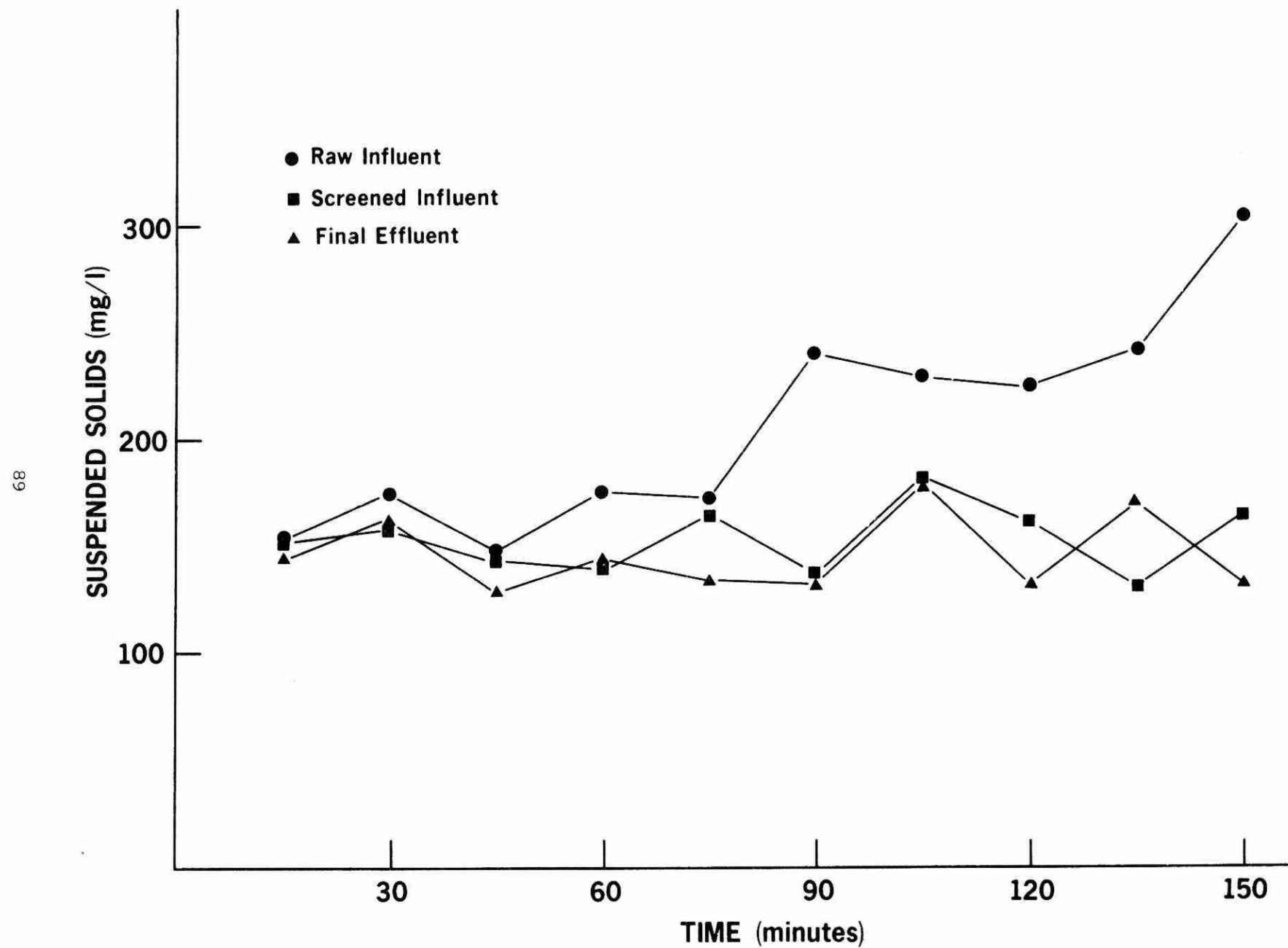


Figure 11. Suspended Solids Concentration Profile During Run 3 (June 19, 1974 P.M.)

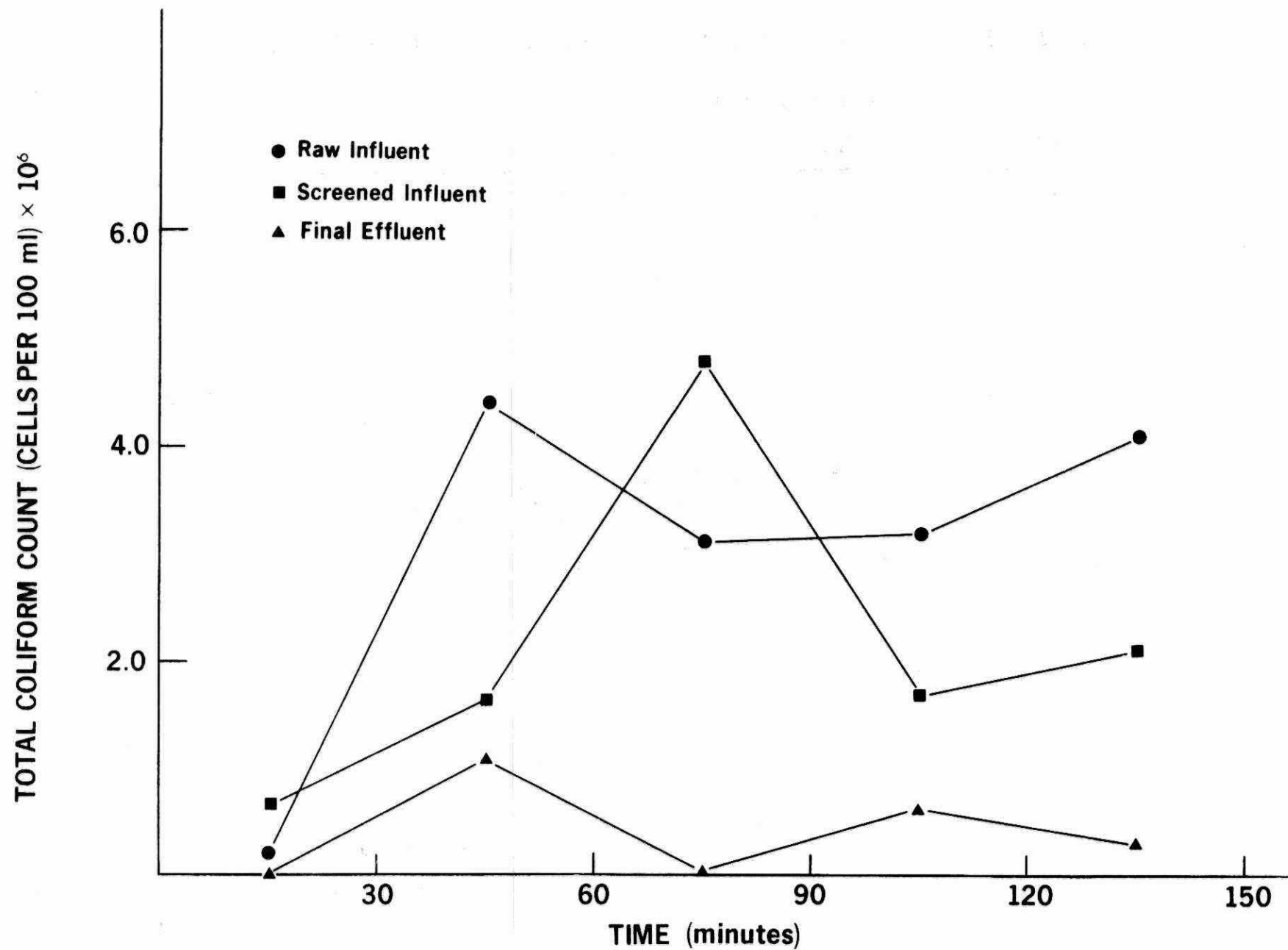


Figure 12. Total Coliform Count Profile During Run 3 (June 19, 1974 P.M.)

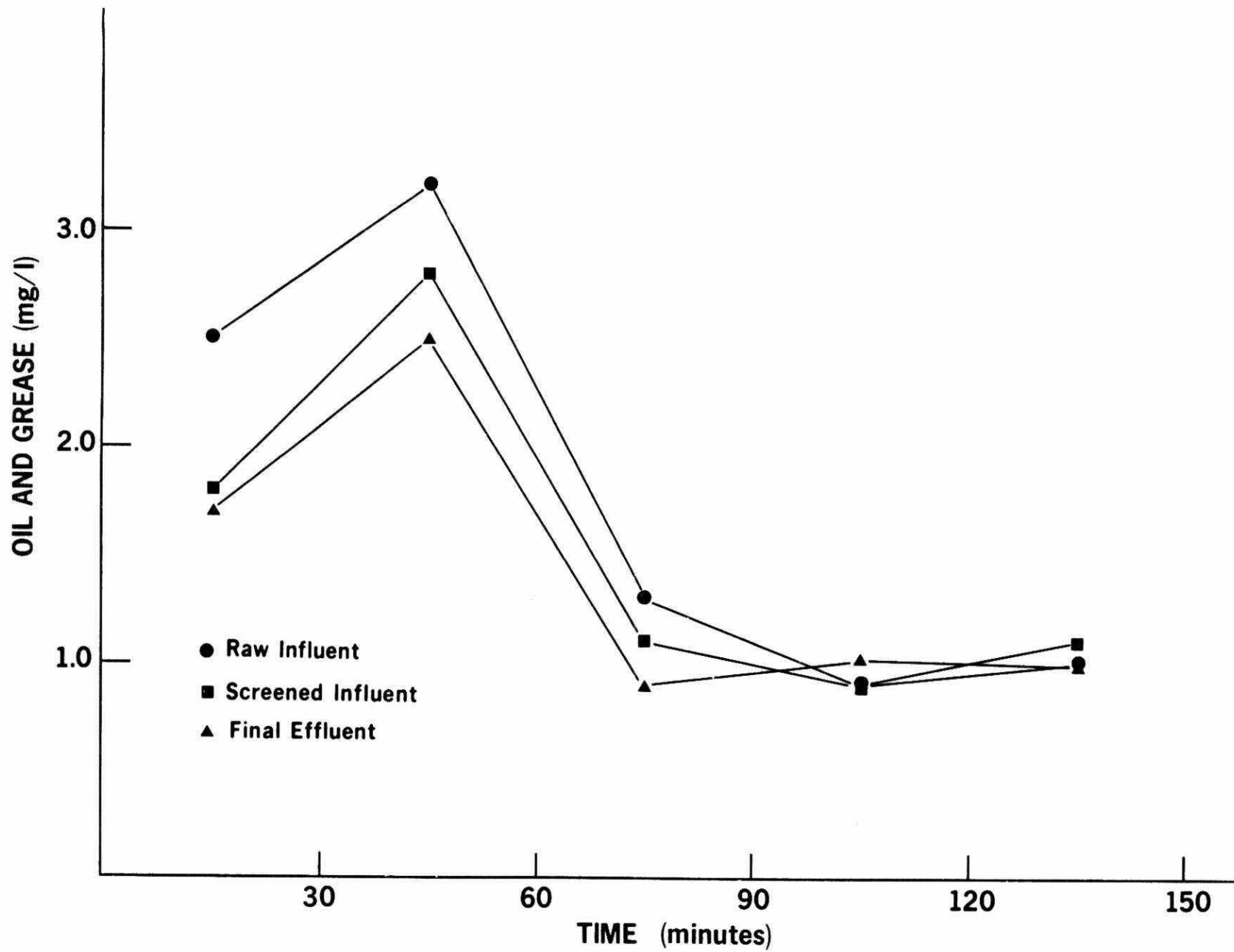


Figure 13. Oil and Grease Concentration Profile During Run 3 (June 19, 1974 P.M.)

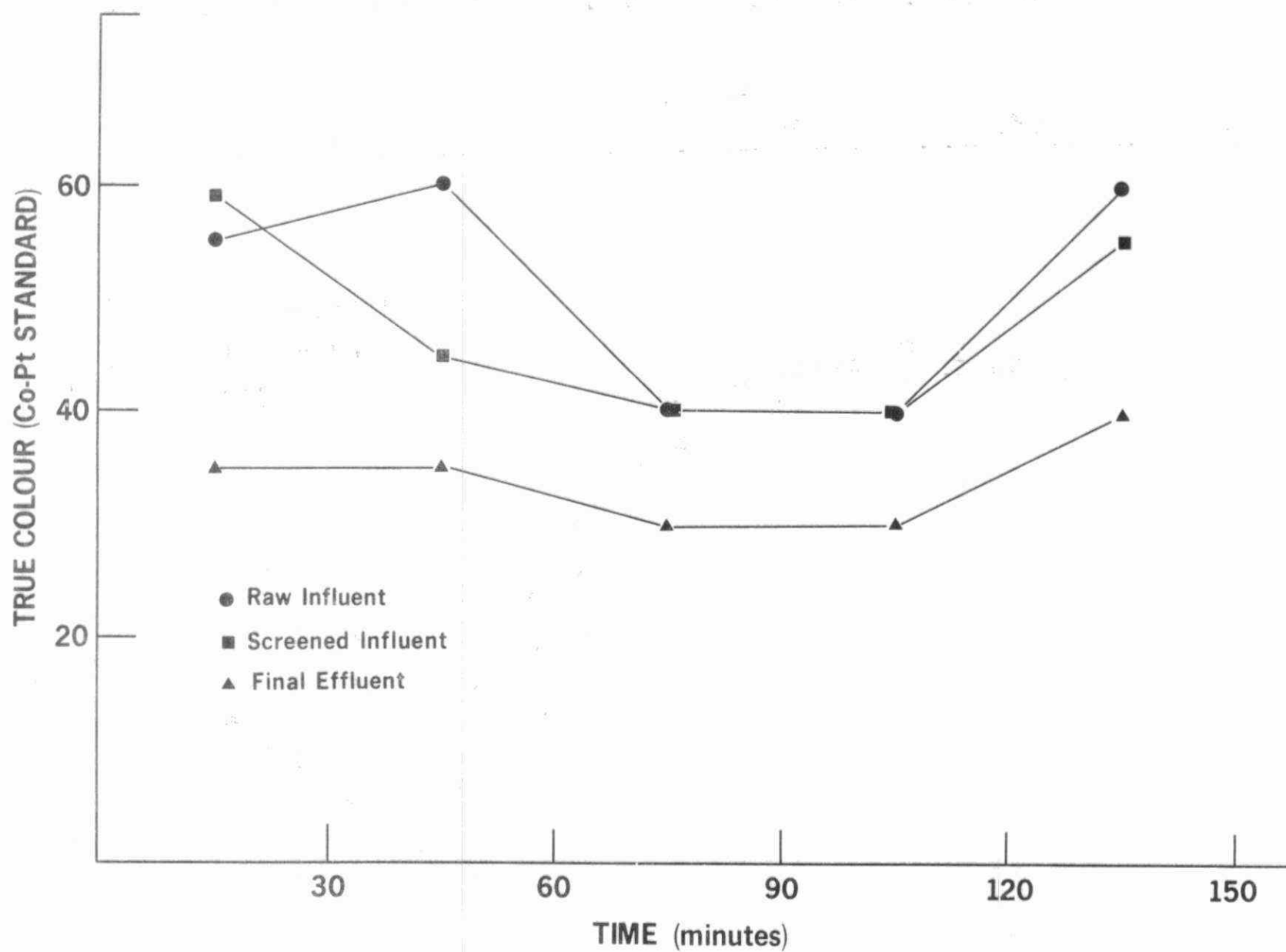


Figure 14. True Colour Concentration Profile During Run 3 (June 19, 1974 P.M.)

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

From the results of the pilot scale evaluation of a Micro-strainer-ozonation system for the treatment of combined sewer overflows, the following conclusions can be drawn:

1. The actual combined sewer overflow sampled during this investigation contained a significantly higher concentration of inorganic solids, primarily in the form of finely dispersed clay particles, and significantly less organic contaminants than the diluted raw sewage used to simulate the overflow during the previous study.
2. No correlation was noted during this study between the hydraulic loading of the microscreen or the suspended solids content of the raw feed and the performance of the Microstrainer in terms of suspended solids removal.
3. In this study, continuous ozonation of the screened effluent was approximately 24 percent less effective in reducing the coliform content of the waste than batch ozonation as applied in the previous study.
4. The overall removal efficiencies of the pilot plant as applied to the actual combined sewer overflow were lower in terms of all measured parameters than those achieved by the system as applied to simulated waste at the West Oakville Water Pollution Control Plant. The absolute decrease in removal varied from approximately 6 to 38 percent. The removal efficiencies for both studies are reported in Table 1.
5. The waste used as feed to the pilot scale treatment system may not be representative of the quality of :typical: combined sewer overflow due to the high concentrations of fine clay resulting from runoff from the local housing construction sites.

6. The preliminary costs of the treatment system as given in the previous report were unchanged by the results of this investigation. The previous cost estimates indicated an equipment cost of \$128,000 per 1000 US gpm and \$113,000 per 1000 US gpm at a design capacity of 10,000 US gpm. Estimated operating costs were \$1.10 per hour at 1000 US gpm.

6.2 Recommendations

The results of the simulated and actual runs for evaluation of the microscreening-ozonation treatment system indicate that the system has good potential in this application. However, further work is recommended before any decision concerning the feasibility of full-scale treatment of combined sewer overflows by this system is made. The scope of this work should encompass the following:

1. Data from sampling programs at numerous combined sewage outfalls should be examined in order to select an overflow site which is typically representative of overflow wastes entering receiving waters.
2. A more elaborate pilot plant installation suitable for year-round investigations should be constructed at the typical combined sewer overflow site and a long-term study initiated in order to optimize the operating conditions for the Microstrainer-ozonation system.
3. During this detailed investigation, the effect of hydraulic loading, differential liquid level across the screen, drum speed, ozone dosage and ozone contact time on the efficiency of the treatment system should be evaluated.

ABBREVIATIONS

A.M.	morning
Al ⁺³	aluminum
BOD	biochemical oxygen demand
cfs	cubic feet per second
COD	chemical oxygen demand
CO-Pt	cobalt-platinum (standard)
DIA	diameter
E.P.A.	Environmental Protection Agency
Fe ⁺ ₃	iron (ferric chloride)
ft	feet
L	length
lb	pound
mg/l	milligram per litre
min	minute
ml	Millilitre
O ₃	ozone
P.M.	afternoon
psig	pounds per square inch (gauge)
scfh	standard cubic feet per hour
TOC	total organic carbon
US	United States
US g	United States gallon
US gpm	United States gallons per minute
US gpm/ft ²	United States gallons per minute per square foot
WPCP	Water Pollution Control Plant
\$	dollar (Canadian)
%	percent

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- Mr. V. Lesnicki and the staff of the West Oakville Water Pollution Control Plant for allowing us to install the unit at their facilities.

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